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Special Scientific Report No. 20

STUDIES ON THE PACIFIC PILCHARD OR SARDINE

(SARDINOPS CAERULEA)

2.--Determination of the Age of Juveniles by Scales and Otoliths

By

Lionel A. Walford and Kenneth H. Mosher

Chicago
1943

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2. - Determination of the Age of Juveniles by Scales and Otoliths[1/]

By

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Aquatic Biologists, Division of Fishery Biology

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[1/] Originally transmitted and approved for publication February 15, 1941.

THE PROBLEM

Up to the present, no method has been developed for determining the age of individual specimens of the Pacific pilchard, or sardine. Lacking a satisfactory substitute, it has thus not been possible to isolate year classes of fish taken in samples of the commercial catch, so as to trace, by serial sampling, their growth in length, or to follow their passage through the fishery.

Such available knowledge as bears on the growth and age of pilchards results from the occurrence of dominant year classes in the population from time to time, which can be readily recognized by their prominence in systematically collected samples of the commercial catch. By this method it has been shown (Clark, 1936, pp. 18-24) that year classes have entered the fishery when their mode was between 190 and 200 mm., that their approximate growth could be followed through as many as five years, when their mode was in the neighborhood of 230 mm., and could be traced with somewhat less certainty, if they persisted in the fishery, for as many as five additional years, when their mode was near 260 mm. Thereafter, according to Clark's work, the hitherto dominant groups have completely lost their identity.

This statistical method is useful only for studying those year classes abundant enough to produce persistently prominent modes in the length frequency curves. However, the method does not permit determining whether a dominant group is composed of one or of several year classes, nor can it be used for studying individually or collectively the more numerous, adominant age classes. Furthermore, as Thompson (1926, p. 187) says, "....our view of the course of a given year-class is probably much distorted by the conditions of selection and by the errors of sampling."

Neglecting, for the purpose of this study, the problem of sampling, an ideal method of analyzing frequency curves would expose and recognize individual year classes from the youngest to the oldest, and of all degrees of abundance. To be accomplished this necessitates age determination of individual fish.

The desirability of such a method was emphasized by Thompson (op. cit. p. 52) who says, "There are two ways in which the abundance of fish may be affected; first by the variations in mortality rate at various stages of life preceding capture, and second by the direct effect of the enrivonment upon the movements or habits of the fish. In the first of these the analysis for size or age must be of supreme utility, being the sole means of determining the relative proportion each age forms of the catch..."

Since the ages of individual fish are determined usually from scales or otoliths, Thompson made a preliminary examination of pilchard scales in the course of his investigation on that species (Thompson, op. cit). He used for this purpose a collection of 194 specimens, ranging from 144 to 228 mm. in length, taken from October 28 to December 2. These were

then read for age, without knowledge of the size of fish, and with frequent changes in magnification to avoid being influenced by the size of the scales. It was found that 20 percent of the scales were illegible, and 54 percent of the readings questionable. In a subsequent examination, with reference to the size of the fish, 61 percent of the readings were questionable, and 25 percent of the scales illegible. A comparison of the two readings indicated that, what with disagreements and illegibility, only about 25 percent of the total age determinations were completely acceptable. When the length of the fish at each age was calculated from the scales by Lea's method (Lea, 1913), Thompson found such discrepancies between the actual lengths of fish at the several estimated ages and the lengths at those ages as calculated from older specimens as further to discredit the dependability of reading pilchard scales. He says, then (Thompson, 1925, p. 53), "So important is the analysis by age regarded at present that it is with the greatest regret that it is temporarily omitted. We--the director and the successive assistants--have vainly attempted to read the age marks on the scales and otoliths. This does not mean that the attempt to utilize them will be abandoned.. . . . we may be able to develop a method of accurately reading the scales according to the age their lengths should indicate. This attempt is already in progress." And, on p. 57, "With this simple presentation of results the use of scale readings is concluded for the time being."

No further studies were carried to completion following Dr. Thompson's preliminary report, however, and no other publications have appeared to date on this subject. Nevertheless, the possibility of determining the age of pilchards from scales and otoliths was not closed, and the belief was expressed from time to time by those studying the species that the subject must be further studied.

Accordingly, by agreement with the California Division of Fish and Game, the staff of the United States Fish and Wildlife Service engaged on pilchard research took as one phase of its program a study of the problem.[1/] This paper, the first report on the results of that study, inquires critically into the utilization of scales and otoliths for determining ages of pre-adult sizes of pilchards; that is, those ranging from the smallest taken by bait fishermen up to those around 185 mm. in length, which is approximately the size at which 50 percent of the females become mature (Clark, 1934). In addition, somewhat less critical results are given for fish up to around 220 mm., at which size 100 percent of the females are mature.

[1/] This study has been made possible only by the cooperation of members of the fishing industry, who aided in our collection of material. The authors are grateful to the following fishermen or dealers, who took an active interest in securing samples of the bait fisheries: Messrs. J. L. Sullivan, Eugene Sullivan, Dominic San Phillipo, and Leonard Schipper at San Diego; Joe Dixon and George Dyson at Newport Beach; S. Carmen and Frank Pugleise at San Pedro; M. Martinelli at San Francisco; and Thomas A. Martin, Jr., at Seattle, Washington. The

Collection of Material

So as to determine the characteristics of an age mark and to observe the time when it forms, scales of young fish of known age, that is to say, young of the year, were studied during an 18-month period beginning with March, 1938. Material was obtained by sampling bait fisheries in southern California, which is the center of this industry, and which is probably the region of maximal spawning (Scofield, 1934). Weekly samples at San Diego, Newport Beach, and San Pedro were taken wherever they were available, i.e., in the fresh fish markets, from fishermen with whom special arrangements to save young pilchards had been made, from canneries, from bait receivers, or from the live-bait tanks of commercial pleasure boats. Enough fish were taken to total, for all localities, about 1500 specimens each week, and to average about 500 from each locality. This work was carried on regularly from March, 1938, to May, 1939. Meanwhile, to have a representation from other parts of the pilchard range, fish were obtained elsewhere by various means.

Beginning November, 1938, and extending through October, 1939, weekly samples were taken of the bait fisheries at San Francisco and Monterey. In addition, several samples from Mexico were supplied by tuna boat captains; and in July, 1938, Captain C. W. Thomas of the coast-guard cutter, Hermes, invited the senior author to accompany the Hermes on a voyage to Magdalena Bay, Lower California, where, for one week, daily samples were taken, totaling altogether 1500 specimens.

Kerckhoff Marine Laboratory of the California Institute of Technology provided laboratory facilities for the southern California station. All the staff members of the United States Fish and Wildlife Service (formerly Bureau of Fisheries) engaged on pilchard research have contributed something toward the progress of this study. Mr. Robert Luckhardt was engaged in sampling the bait fisheries in southern California and San Francisco; Mr. Ralph Silliman canvassed the possibilities of obtaining young pilchards in Washington and Oregon. Mr. O. E. Sette, in charge of the pilchard investigation, gave advice and criticism throughout the entire course of the study.

Mr. William Bowen, microscopic technician of Stanford University, supervised sectioning and staining of the scales. Preparation of the scales and otoliths for microscopic examination, subsequent clerical work on the statistical processes, and the preparation of graphs were done by W. P. A. Projects 702-3-1 and 10917, respectively. Microtechnical and clerical work was done by N. Y. A. assistants, furnished through the Stanford Student Employment Office; and Stanford University has generously provided the working quarters of the South Pacific Investigation, giving the staff free access to its libraries and other useful facilities.

Finally, we acknowledge with gratitude the critical reading of the manuscript by Dr. W. F. Thompson of the International Pacific Salmon Fisheries Commission, and Dr. Frances N. Clark of the California State Fisheries Laboratory.

Meanwhile, since it had been reported that young pilchards are taken occasionally along the Washington coast by fishermen, and appear from time to time in the stomachs of salmon caught there, one of the Service's staff, Mr. Ralph Silliman, was stationed at Seattle to secure any specimens that might be obtainable. By examining a large number of salmon stomachs and by making special seine hauls, Mr. Stilliman obtained a sample of young fish at Westport in April, 1938, and others at Tokeland, Willapa Bay, in September and October. (Silliman, unpublished manuscript.)

Altogether, 175 samples were taken, totaling 71,800 fish. For measuring, the fish were laid on a board especially designed to obviate numerical bias on the part of the operator, (Sette, 1941) and the body length (i.e., tip of head to end of fleshy part of caudal peduncle) read to the nearest millimeter. For each sample, scales were removed from the first 50 to 75 specimens having any suitable ones still adhering. Ordinarily they were taken only in an area of about 1 1/2 centimeters square centered by the tip of the pectoral fin, or, in a few exceptions, as close to that area as scales were available. They were removed with forceps, dipped in water, wiped with the fingers when still fresh to remove adhering slime and tissue, and preserved in envelopes. Otoliths were removed from most of the specimens from which scale samples were taken. These were washed in water and preserved dry in envelopes. Scales were taken from 11,500 fish; otoliths from over 10,000. Not all these were read; only enough to secure reasonably adequate representation from each month.

AGE AND GROWTH OF JUVENILE PILCHARDS AS JUDGED FROM LENGTH FREQUENCY CURVES

Because the first two year classes are each usually recognizable from older fish by their distinctive size, length frequency curves are useful for identifying the age of young fish up to two years. They therefore provide a starting point for associating age with number of rings on the scales and otoliths.

Under simple conditions such an extensive sampling as was carried on should provide a series of frequency curves truly representing the total population of young pilchards in the sea. Unfortunately, for various reasons, conditions are not simple. Judging from the protracted spawning season (Clark, 1934) and the extensive spawning range (Scofield, 1934; Silliman, unpublished manuscript), the year's brood along the coast probably consists of a number of groups of fish, each representing an individual wave of spawning in a particular locality. Since pilchards, like other species with similar habits, appear to school more or less according to size, it is conceivable that, so long as the several groups differ in size, each will travel more or less independently, entering and leaving the field of the bait fishery at irregular intervals, thus offering the fishermen only a limited availability. This effect must be enhanced by the fact that bait fisheries do not cover the entire ground

traversed or occupied by pilchards--there are no such fisheries of importance north of San Francisco, or between Monterey and Los Angeles Counties, or between Turtle Bay and Magdalena Bay, nor do the bait boats operate farther than about 15 miles offshore. In addition, the method of fishing is such that only those fish schooling near the surface are caught, while those schooling deeper are missed. Moreover, the fishermen tend to seek certain sizes; in some places the smaller fish, in others the larger, depending on local demand. For these reasons only a highly and variably selected part of the population could be available to us.

The effect of this selectivity might be partly eliminated by weighting the samples according to the catch, or according to relative abundance at the several localities; but statistics bearing on the bait fishery or on regional abundance are not available, and such weighting is therefore not at present practicable. Because the samples were of various sizes they were all weighted equally (to 1000 fish); likewise, the monthly totals of the weighted samples at the several ports (to 1000 fish); and the totals of all California ports thus weighted were summed by months. The original data were divided into two parts, as indicated by vertical lines in figure 1, the one comprising what was judged to be approximately all the youngest year class, the other the older ones. Each part was weighted separately, to 1000 fish, thus emphasizing the height of the several modes without regard to their relative abundance.

Judging from figure 1, a new complex of groups of fish first appeared in appreciable numbers in the California samples in June, in 1938, ranging in body length from about 40 to 95 mm., and having several modes, the dominant one at 70 mm. Save for a few specimens in May, fish of that size-range were not available earlier, in spite of every effort to obtain them, and were not available again through May of the following year. A fairly similar group appeared in the bait fishery of San Pedro in 1922 (fig. 2; Higgins, unpublished manuscript), showing that such occurrence is probably normal. It is probable that this group represents the youngest year class. This conclusion is based on the following considerations: in the most sinistral group of modes for June, 1938, in figure 1, there is a range of about 55 mm. This leaves only 40 mm. to the left in which to include a possible younger year class. It would be extremely unusual for the zero year class to have a narrower range than the I's; or to be less widely separated from the I's than the I's are from the II's; or for the first year of growth to be less than the second. But, nevertheless, even if there were an additional year class, then the fish in the above mentioned 40-mm. range should have grown almost, or quite past the 40-mm. point by the following May. Before that time, they should have been taken by the nets of the bait fishery, which, judging from figure 1, could hold fish as small as 40 mm. That no such fish were taken in our samples is strong evidence that they did not exist in the waters of the area studied. It seems beyond question, therefore, that the most sinistral group of modes for June in figure 1 does represent fish produced in the spawning season of 1938.

Subsequent growth can be traced by the monthly progression in the position of that group from June, 1938, through May, 1939, when the dominant mode was near 120 mm. It is evident that the year class was composed, at first, of several subgroups, the availability of which fluctuated more or less independently during the year. This accounts for irregularities in the progression.

As for the ages of fish older than 0 year class, it may be supposed that in curves to the right of those belonging to year class 0, the smallest fish, those around 84 to 100 mm., in March, 1938, were the smallest one-year olds, and may be homologous with those ranging from 130 to about 170 mm., in October, 1938, and to those of an undeterminable range above 150 mm., in May, 1939. From figure 3 it is shown that fish as small as 150-160 mm. were taken in the fall commercial fishery for "adults" at Monterey in October, 1939. If this October, 1939, curve of figure 3 be comparable with the October, 1938, curve of figure 1, it could be concluded that at Monterey in 1939 some pilchards entered the fall commercial fishery when in their second year. Nothing can be told by inspection of frequency curves in figures 1 and 3 about the ages of the fish larger than these sizes; they may be all one-year olds, or there may be an admixture of older fish. A knowledge of the age composition of these fish is possible only by determining the ages of the individual specimens.

The modes of curves in figure 1 do not coincide in position with analogous modes indicated for 1921 and 1922 (fig. 2). These differences may mean that the growth rate of the comparable year classes was different, or that survival was different; or it may mean that selection was different in 1938-39 than in 1921-22. In any event, it appears from these differences that one cannot generalize, as to size and growth, from one year class to another, or from the sampling of one year to that of another.

Young pilchards collected in Lower California in July and August, 1938, from Washington in April, September, and October, 1938, and from Oregon in May, 1939, do not correspond in size to those taken in California during those months. This indicates that the California bait fishery does not draw from the entire juvenile pilchard population of the Pacific coast. Lacking data for Lower California, Washington, and Oregon in other months, little can be judged from these data as to the age of fish represented in the available frequency curves. Are the fish taken in Lower California in July and August, 1938, fish in their first year, or their second? The same question may be asked about fish taken in Washington in April, September, and October, 1938, or at Coos Bay in May, 1939. These and other questions bearing on the age composition might be answered by study of the scales and otoliths.

AGE AND GROWTH OF JUVENILE PILCHARDS AS JUDGED FROM SCALES AND OTOLITHS

The Use of Scales for Determining Age

The scales of pilchards are typical of fishes in the family Clupeidae. Like herring scales, they are sculptured on the upper surface of the unexposed part with low transverse folds, (Figure 12) which are in most specimens variously interrupted with rather coarse radii; and they are, with few exceptions, almost entirely unsculptured on their exposed part. Like herring scales, they differ from scales of many other species that are used for age determination, such as cod, haddock, or salmon, in that the surface folds--"circuli"--are typically not circular or concentric, but transect the scale from the dorsal to the ventral margins. Careful study has shown no irregularity in spacing between these folds, extending clear along their length, that can be related to age; there is no indication of winter narrowing of spaces, or of spring widening; nor any periodic change in texture that involves entire folds.

Close inspection of an adult pilchard scale, however, reveals other marks, concentric with the margin, along the line of which the transverse folds are more or less distorted and irregularly spaced. These are similar to the year marks on the scales of European herring, and are what Dr. Thompson counted as annuli in his study (1926) reviewed above, and also what the authors of this paper have considered as such.

If it could be demonstrated that they are really annual marks, the problem of determining the age of pilchards might then become a mere matter of counting them. However, they are not distinct in ordinary preparations, and special mounting is necessary to bring them out.

It was found during the present study that unless a pilchard scale be perfectly clean it is almost invariably useless for age determination. Because of the tenacity of the dried mucous, blood, guanin, etc., to the delicate surface structure, dirty pilchard scales cannot be cleaned, once they have dried, by washing in water and rubbing. Consequently, the scales must be cleaned at the time they are removed from the fish, before they are preserved in envelopes. For dirty, dried scales, a moderately satisfactory method of cleaning is the following: Soak the scale until thoroughly moistened in a 10 percent solution of sodium hydroxide, then rinse in water, rub with fingers to remove offal, rinse in 10 percent acetic acid to neutralize, and then rinse in clean water.

For mounting, many liquid media were tried: glycerine, water, mixtures of the two, and various kinds of oils and glues. These substances all rendered the scale too transparent for use, seriously decreasing the visibility of the surface structure, an effect found to be more or less proportional to the refractive index of the mounting medium (see figures 25 and 26).

It was found that pilchard scales appear to excellent advantage and the surface structure is brought out in bold relief in a medium of air. Accordingly, the specimens were mounted dry,--6 or 8 for each fish,--between two glass slides stuck together at the ends with glue and clamped together tightly, until the latter dried, so as to flatten the scales and insure their remaining in place.[2/] To mount scales from 100 fish required about 6 hours.

The specimens thus prepared were examined with the aid of a projecting microscope so arranged that the projected image appeared on the table beside the microscope. It is the impression of the authors, perhaps purely personal, but probably not, that the year marks appear much more clearly in the projected image than when viewed directly through the microscope.

For each specimen a punch card designed for the ready tabulating and sorting of data was laid on to the image so that a millimeter ruler printed on the card extended along the mid-longitudinal axis of the sculptured part of the scale, its zero line coinciding with the base of the latter. Lines were then drawn through the ruler where the latter was crossed by "annuli." Subsequently there were recorded on the card such pertinent data as sample number, length of fish, locality and date of collection, dimensions of scale and position of marks, etc. Thus a permanent quantitative record was obtained for every examination.

To learn the characteristics of an annual mark, scales of young pilchards were examined over the course of a year. A concentric mark was observed to have formed consistently by early spring. As a result of these preliminary examinations, we recognized as annuli those marks having the following characteristics:

> An annulus is concentric with the margin of the scale. It is not always a sharp or unbroken line; nor are the segments of an interrupted annulus always perfectly cocircular (if the shape of a scale may be called circular in this discussion). But the course of an annulus, continuous or broken as it may be, can usually be traced, by careful scrutiny if necessary, entirely around the sculptured part of the scale from left-hand to right-hand margins. Sometimes they can even be followed around the unsculptured part. Annuli are clearly separated from each other and do not ordinarily meet at any point. If an annulus has formed, it is present in all the normal scales of an individual.

We have recognized as adventitious, or otherwise unperiodic ("false rings") those marks distinguished by the following characteristics:

[2/] While this paper was in manuscript, a publication by Aikawa (1940) was received. It describes the same mounting technique as that used in our study.

They are merely short or unassociated arcs; or if they completely circle the sculptured part, they are usually not concentric with the margin; furthermore, they frequently join an annulus at the base. In any case, they may be less distinct than an annulus, being vague and indefinite, or they may be much more distinct, having a scarlike appearance; that is, with very pronounced irregularities of pattern, the folds being broken or otherwise obviously abnormal (See figures 24,27). They rarely appear in all the scales of an individual.

For the first annulus, which is sometimes difficult to distinguish from a scar, especially if it be nearer the center than normal, the following rule was applied: A mark conforming to the above description of an annulus was counted as an annulus, provided it appeared in all the scale specimens examined; but if in one or more specimens said mark had an obviously scarlike appearance, it was considered a false annulus, and was not counted.

Although a false annulus may appear at any time during the year, a true annulus is formed only once annually, and during a certain season. The distance between annulus and the margin of the scale--the marginal increment--represents the growth since the annulus was formed. For fish in their first year, the marginal increment is the distance between the base of the sculptured part and the margin of the scale. If one were choosing unperiodic marks to determine age in samples of fish, then frequency curves of the marginal increments should show no progress in width during the year, for there should be no consistency in the time of appearance or position of the marks. But, on the other hand, if one were choosing truly annual marks, there should be one time of year when the marginal increments are narrowest, and another time when they are widest, with intermediate widths between. This argument is the basis for the following test as to whether or not the annulus is formed once yearly.

A stratified random sample of 3,000 mounted scales was drawn (by Mosher) so as to represent about equally all the months of the period studied, and, where possible, to represent equally northern and southern California material. The labels of the slides were then masked, the slides mixed, and drawn at random from a box. The scales were then examined (by Walford), and measurements recorded as described above. Since the annulus is not apparent at the time it is forming on the very edge of the scale, but only sometime afterward when enough marginal growth has occurred to set it off clearly, no zero marginal increments were recorded. Figure 4 shows the marginal increments thus measured for scales with 0, 1, and 2 rings.

Obviously in the specimens of these year classes examined, the marginal increments were relatively narrow in April, 1938, and increased in width from then until the following fall, when narrow marginal increments began to appear again. In other words, the marks called annuli in this study must be really annual in occurrence, and may be used to determine age, at least for the first two years of life.

It has been argued (p. 5) from figure 1 that the group of small fish taken in June, 1938, with a dominant mode near 70 mm. represented fish spawned in 1938. According to the scale studies, the scales of these fish were consistently without annuli. It may therefore be supposed that fish with one and two rings on their scales at that time of year were of year classes 1937 and 1936, respectively. In November, one annulus became evident near the margin of some specimens identified from figure 1 as belonging to year class 1938. By March, all the members of this class had one annulus, while those having two and three were now identified with year classes 1937 and 1936, respectively.

If we choose an arbitrary boundary to separate "narrow" from "wide" marginal increments, say the 32.5 mm. point in the data used for figure 4, it is possible to define a time when the annulus became evident during 1938-39. The proportion of fish having "narrow" marginal increments, in percentage, by months, is given in figure 5. In southern California, according to figure 5, an annulus became evident, on the average, in pilchards of year classes 1937 and 1938 early in January, when 50 percent of the specimens examined showed a "narrow" marginal increment, and 50 percent a "wide" one. In central California the annulus did not appear until late February for year class 1938, early March for year class 1937.

This difference between central and southern California held consistently during the months for which comparable data are available (fig. 6). Since the scales were read without knowledge of the catch localities, this is further evidence that the marks called annuli had not been formed sporadically.

The annulus, being a very narrow zone, practically a line, became evident only when enough growth had occurred to expose it. Therefore it must have formed some time previous to the late fall and winter, probably in the late summer and fall, when, judging from figure 5, growth of the scales is slight.

If the evidence be accepted that the marks counted as annuli are really year marks, it remains to be shown whether the counts can be made with reasonable consistency. To test this, a stratified random sample of 242 scales that had already been read was drawn (by Mosher) from among some 3,000 scales, so as to represent with approximate equality the first four year classes. The labels of the slides were then masked, and the scales read for the second time (by Walford). The results, given in Table I, indicate that one person can count what he defines as year marks consistently.

To test the similarity of readings by two persons working separately, a sample of 367 scales from the fall fishery of 1939-40 that had been read by Walford was read independently by Mosher, with no previous experience at scale reading, and recorded as described on page 8. The results, given in table II, show a high percentage agreement between the two sets of readings, and indicate that at least two

persons can identify the same marks as annuli, and count the same number of rings in a significantly large proportion of the cases. The results summarized in both tables I and II give evidence that a year mark has been defined on page 8 in simple enough terms to serve as a usable guide. They do not necessarily indicate the percentage error in the counts of age rings, or in the relation between the number of rings present and the number of years of life, for it is well-nigh impracticable to obtain such a measure. For the present study, however, it is likely that this error is not disproportionately large; otherwise, figure 4 would have been a chaotic picture.

TABLE I.-Comparison of Original Scale Readings With Those Made at a Later Time by the Same Person.

Number of annuli in second reading	Number of first readings matching second	Number of first readings not matching second	Percentage agreement
0	64	0	100
1	50	4	93
2	70	3	96
3	49	2	96
	233	9	

TABLE II.-Comparison of Scale Readings by Two Different Persons

Number of annuli in second reading	Number of first readings matching second	Number of first readings not matching second	Percentage agreement
1	114	7	94
2	123	14	90
3	63	12	84
4	30	4	88
	330	37	

Although in this study the labels of the slides were masked, so as to obviate any possible bias caused by knowledge of the size of the fish, there was no way of concealing the size of the scales. The authors may thus have been influenced by scale size, tending to assign older ages to large scales and younger ages to smaller ones. If this influence were serious enough to dominate the determinations, the fact might become evident from a correlation study on age, body length, and scale length.

The latter two variables are rather imperfectly correlated, in the present material, with considerable variation of body length for each scale length, and also of scale length for each body length. (The coefficient of correlation between body length and scale length was .78, with P of less than .01. The coefficient of regression for scale length on body length was .84; that for body length on scale length was .73.) There is, of course, no way of knowing the true magnitude of correlation between age and either of these two variables. There are these possibilities for consideration, however:

(A.) Age might be more highly correlated with scale length than with body length. Then, on measuring scales from a number of fish with identical (or nearly so) body length, we should expect some degree of positive correlation between age and scale length. In addition, if, in our age determinations we had been influenced by the size of the scales, rather than the number of age marks, we should expect the above correlation to be enhanced. To examine this possibility, a collection of 987 scale measurements ranging from 190-219 mm. of projected image, and compromising four year classes, was divided into groups of ten-millimeter classes according to body length; and for each of these body-length classes the coefficient of correlation between age and scale length was calculated. The results, given in table III, show no significant correlation between these two quantities. The probability (P) is high, averaging .416, that if there were no correlation whatever, the coefficient could, by random causes alone, be as high as indicated. This lack of correlation is evidence that the age determinations were not influenced by scale length to any appreciable degree. Incidentally, it is also evidence that there is no intrinsic correlation between scale length and age; i.e., no correlation other than what results from the dependence of scale length on body length.

TABLE III.-Correlation (r) Between Age and Scale Length for Fish of Identical Classes of Standard Length.

Body length of fish in millimeters date	N 1/	r	P
190-199 Nov. 1939	82	.21	> .05
190-199 Dec. 1939	91	.19	> .05
200-209 Nov. 1939	236	-.04	> .5
200-209 Dec. 1939	193	.002	> .9
210-219 Nov. 1939	174	.12	> .1
210-219 Dec. 1939	211	.003	> .9

1/ Number of specimens

(B.) If, on the other hand, age is more highly correlated with body length than with scale length, we should expect some degree of positive correlation between age and body length among fish with identical (or nearly so) scale length. To examine this possibility, scales of 559 fish taken in the fall commercial fishery for adults, comprising four year classes, and ranging from 190-219 mm. in body length, were divided into 10 mm. classes according to scale length. The coefficient of correlation between body length and age within each of these scale-length classes was then calculated. These calculations (Table IV) show significant correlations between these two quantities, with a low probability (P), averaging less than one in one hundred, of arriving at such high values by chance alone, if there were no correlation. These results could not have been modified by any influence of scale length, for the design of the analysis precluded that.

TABLE IV.-Correlation (r) Between Age and Body Length for Fish Having Identical Scale Length Classification.

Scale length (mm. of projected image) Date	N 1/	r	P
190-199 Nov. 1939	55	.70	$<.01$
190-199 Dec. 1939	50	.43	$<.01$
200-209 Nov. 1939	81	.76	$<.01$
200-209 Dec. 1939	84	.68	$<.01$
210-219 Nov. 1939	152	.52	$<.01$
210-219 Dec. 1939	137	.46	$<.01$

1/ Number of specimens

(C.) The results reached under A and B are conclusive; but, nevertheless, consideration might be given to the possibility that age is correlated in like degree with both body length and scale length. Then the coefficient of correlation for age on body length with fish having identical (or nearly so) scale length, and that for age on scale length with fish having identical (or nearly so) body length should be about equal. Then, if in our age determination, the authors had been influenced by the size of the scales instead of the number of age marks, the correlation coefficient for age on body length should

tend to be the lower, and that for age on scale length the higher value of the two. Obviously, judging from tables III and IV, just the opposite of this result is demonstrated. Thus, so far as can be deduced from this evidence, there is no confirmation of a supposition that scale length significantly influenced the age determinations in the present study. Indeed, it appears unlikely that it was of any influence whatever.

The Use of Otoliths for Determining Age

Another line of evidence by which to judge the correctness of scale readings is given by a study of otoliths. This was carried on simultaneously by Mosher, independently of the scale work, and without reference to it.

Otoliths were collected from 6000 fish of the same series, described above, as represented by scales. These were washed and preserved in envelopes in the same manner as the scales. They were subsequently mounted as follows: A piece of thin cardboard was cut in the shape of a standard microscope slide, but about 1/8 of an inch shorter and narrower. This was punched with eight small round holes, and laid over a drop of Canada Balsam on a microscope slide. Into each hole was placed an otolith, then a drop of Canada balsam; and any air bubbles were burned out with a hot needle. Another microscope slide was laid on the mount as a cover glass, and the preparation put in a warm place to harden.

The mounted otoliths were examined in a micro-projection apparatus and the dimensions recorded on punch cards, as described on page 8, with the base of the ruler placed at the center, as indicated in Figure 28. The inner edge of each translucent zone was taken as representing the year mark. These readings were later checked by examination with a binocular microscope and reflected light, which brought out the year marks sharply as blue-black against the white opaque intervening zones.

Preliminary examination of otoliths from fish known to belong to 0 year class and collected over the course of 12 months established the following criteria of a year mark:

> An annulus is a more or less translucent band concentric with the margin of the otolith, the intervening spaces being opaque. It can usually be traced entirely around the otolith, although it is more easily observed at the blunter anterior end than at the sides or posterior end. Annuli tend to be zones rather than lines.

Marks having the following characteristics were considered to be adventitious, or otherwise unperiodic:

> Though translucent, they tend to be lines rather than zones; they frequently meet an annulus at some point.

Although the first two year-marks are generally well defined on otoliths, the third is less so; and the subsequent ones are so closely crowded and so easily confused with false year marks that they cannot be counted with a very high degree of confidence.

To determine whether or not the "annulus" is formed once annually in otoliths, a stratified random sample of 2600 specimens, representing about equally all the months of a year, was examined, and the marginal increments, which included the band comprising the annulus, were measured as described on page 8. To avoid possible confusion between true and false year marks in otoliths, no translucent zone was considered until it was wide enough to preclude its being a false annulus.

The marginal increments for otoliths, when plotted in the same way as had been done for scales in figure 4, proved also to be narrowest during one part of the year, and to increase progressively thereafter. In figure 7, age classes 1937, 1936, and 1938 have been assigned to fish having, at their first appearance in our samples, one, two, and zero rings on their otoliths, respectively. It is evident, in figure 7, that the annulus is a true year mark in otoliths as well as in scales, and became visible earlier in otoliths than in scales in 1939, showing as early as June in some specimens, and by October in all. This is consistent with the conclusion reached above that in scales the year mark forms during the summer and fall.

To define more exactly a time when the annulus became evident in otoliths, we can choose, from the data used for figure 7, arbitrary boundaries to separate "narrow" from "wide" marginal increments, as was done for scales. Thus the 35-mm. point was selected for year class 1938, the 20-mm. point for year class 1937, and the 15-mm. point for year class 1936. The proportion of fish having "narrow" marginal increments, in percentage, by months, is given in figure 8. According to figure 8 the annulus on otoliths became evident earlier among older fish than among younger ones. For year class 1936 this occurred early in July when 50 percent of the specimens examined showed a "narrow" marginal increment, and 50 percent a "wide" one. In fish of year class 1937 this occurred in late July, and in year class 1938 in early August.

Parallel age determinations, by scales and by otoliths, were made in 1036 specimens. The results, given in table V, indicate a high agreement for the first two year classes, and a moderate agreement for the third. Doubtless a large portion of the disagreements among the three-year-olds may be attributed to the difficulty of counting the rings on otoliths with more than two marks.

Growth of Juvenile Pilchards

The age composition of samples from the 1938-39 bait fisheries of southern and central California, as determined by scales, is indicated in figure 9 where the growth of fish comprising year classes 1938 and

1937 can be traced from early youth to the size at entrance into the fall commercial fishery for adults; and though data for year class 1936, also included, are rather scanty, they are sufficient to give some indication of size composition and growth. A similar figure made from otolith readings was essentially identical with figure 9, and is therefore not here reproduced (Table 6).

TABLE V.- Comparison of Age Readings by Scales and by Otoliths

Number of annuli by scale reading	Number of otolith readings matching scale readings	Number of otolith readings not matching scale readings	Percentage agreement
1	355	6	98
2	419	36	92
3	166	54	75
	940	96	

Precise knowledge of the growth of the pilchard is seriously impeded by the difficulties of sampling, discussed on page 4. Growth is illustrated in figure 10 (Table 8) where the average lengths of each year class among fish taken in California are plotted by months. Data are from the bait fisheries and from the fall commercial fishery for adults.

The differences from year to year between the average length of fish of corresponding ages in figure 10 are no doubt due in part to actual differences between the year classes. In large part also, however, they are due to differential selection. Moreover, variations from a smooth growth curve for individual year classes are probably due to varying selection.

Samples of fish of year class 1937, taken from April, 1938, to May, 1939, were mostly from the southern California bait fisheries, where there is a tendency for bait fishermen to select against the larger fish, resulting in over-representation of the smaller members of that year class. Furthermore, judging from figure 9, there was a tendency for the larger fish of year class 1937 to leave, and for smaller ones to enter, the field of the fishery at intervals during the year. The consequent selective availability undoubtedly contributes to the irregularities of figure 10. From June to October, year class 1937, as well as 1936, was sampled from the San Francisco bait fisheries, which seemed to select against the smaller fish, producing an effect opposite to that obtained in southern California. At the same time, beginning in September, samples were taken from the fall fishery for adults at Monterey. Here a selection results from a rather complex differential availability. Fish of year class 1938 taken in the fall commercial fishery for adults appear to represent the larger membersof their class, perhaps partly

because the latter were schooling with older fish, and partly because the fishermen consciously selected against very small fish, which have low economic value for reduction or canning purposes. In general the fish available during most of the fall are smaller and younger than those available during the winter. This results in a selection, by differential availability, against the larger fish of year classes 1937, 1936, and 1935.

Because of these differences in demand and availability from place to place, from fishery to fishery, and from month to month, and the consequent imperfections in our sampling of the population, figure 10 shows a very irregular series of points to which such a curve as might be fitted could only rather roughly represent the average growth of the pilchard in California during its first four years. Nevertheless, in all essential respects, the points, as far as they go, are in harmony with the points (designated by large asterisks) obtained from the modes of frequency curves in figure 2, and from data published by the California State Fisheries Laboratory (Clark, table 2, 1936).

Difference in Size Between Localities

The foregoing discussion has referred only to fish collected in California. The statistics given in figure 10 and table 8, therefore, describe only a portion of the total Pacific coast population of those year classes. That this is true is shown by figure 11, which gives the age composition of such samples as were obtainable in Washington, Oregon, and Lower California. Obviously, if it were possible to sample properly the entire coast, the range of each year class would probably be broader than shown in figure 9. Though the data from northern and southern grounds are too scanty to deserve very extensive interpretation, they show that fish found north of California in 1938-39 averaged smaller by the end of their first year than those of the same age from California; and fish taken from Lower California averaged larger than those of the same age taken in California. These differences are no doubt reflected in the scale growth increments, and should furnish a useful tool for studying migrations.

DISCUSSION AND CONCLUSIONS

The scales and otoliths of most fishes are characterized by folds or sculpturing in which variations of pattern may be related to age. If they are so related, for a given species, they need not correspond in number with years of life; or, if they do correspond, they may not be recognized, for they may be so obscure as to be counted incorrectly. It is no wonder, then, that scale and otolith reading is a process peculiarly open to subjective influences, and requires, for serious work, a stringent test and proof of validity.

In the foregoing pages it has been demonstrated that, if they be properly prepared, scales and otoliths of juvenile pilchards (Sardinops caerulea), show rings that are associated in number with age. It has been shown that these rings are formed once yearly, at a definite time of year, namely, the summer and fall. They therefore correspond in number with years of life. Though they are sometimes relatively obscure, the rings present may be counted with what appears to be significant accuracy, say 85-95 percent for the first three year classes; and results, which a later report will cover, give promise of extending the use of scales to much older ages. Of the scales examined during this study, over 99 percent were considered legible. Those not legible were generally specimens that had been improperly cleaned, or that had regenerated centers. The age determinations were in all cases made without reference to the size of the fish, and there is evidence that the operators were not unduly influenced by the size of the scales.

The counts of annuli on otoliths were found, by an independent study, to agree with those on scales. It is the opinion of the writers, however, that otoliths are less useful than scales for determining age of pilchards beyond the third year.

Judging from scales and otoliths of juvenile pilchards taken from the bait fisheries in California during 1938 and 1939, and from the fall commercial fishery for adults in 1939, fish of the year class 1938 had a modal length around 70 mm. when they first appeared in the bait fishery in June, 1938, growing to near 120 mm. by the following April, by which time the first annual mark has formed; and fish of year class 1937 had a modal length near 160 mm. when their second mark had formed. Because of the rather complex selection resulting from the requirements of the fisheries, as well as from variations in availability, the sampling was highly imperfect, and these figures are mere approximations. Furthermore, they apply only to fish taken from California fisheries.

Young specimens collected in Lower California were larger than those of corresponding age taken in California; and those taken in Oregon, Washington, and British Columbia were smaller. These differences suggest further applications of the study of pilchard scales, for they are, no doubt, reflected in differences in corresponding scale growth increments among the populations of the different regions. Thus the scales may prove useful for studying the migrations of the pilchard, as well as for determining their ages.

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TABLE VI -Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	MARCH, 1938 Total fish measured	Fish aged From scales Year classes 37	36	From otoliths 37	36	APRIL, 1938 Total fish measured	Fish aged From scales Year classes 37	36	From otoliths 37	36	May, 1938 Total fish measured
36	-	-	-	-	-	-	-	-	-	-	3
40	-	-	-	-	-	-	-	-	-	-	1
44	-	-	-	-	-	-	-	-	-	-	1
48	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-	-
80	1	-	-	-	-	-	-	-	-	-	-
84	49	-	-	-	-	-	-	-	-	-	-
88	311	-	-	-	-	-	-	-	-	-	-
92	174	-	-	-	-	3	-	-	-	-	-
96	47	-	-	-	-	32	-	-	-	-	-
100	17	2	-	-	-	154	-	-	-	-	-
104	11	4	-	5	-	365	-	-	-	-	-
108	23	5	-	8	-	577	-	-	-	-	10
112	23	2	-	10	-	904	-	-	-	-	58
116	38	7	-	12	-	691	1	-	-	-	266
120	41	8	-	11	-	507	1	-	3	-	412
124	46	7	-	8	-	437	4	-	10	-	354
128	48	6	-	4	-	440	7	-	7	-	355
132	25	9	-	10	-	377	5	-	6	1	383
136	17	9	1	7	-	304	7	2	5	-	360
140	10	7	1	5	-	139	4	-	14	1	357
144	9	1	5	1	-	66	3	1	5	2	306
148	8	2	3	1	2	43	9	-	11	-	255
152	11	2	1	-	-	22	9	2	9	2	188
156	9	-	-	1	-	19	11	5	5	2	116
160	6	1	2	-	-	10	5	4	1	3	42
164	1	-	1	-	-	1	2	9	1	6	30
168	5	-	1	-	-	2	-	5	-	5	33
172	2	-	-	-	-	1	2	5	-	3	31
176	-	-	-	-	-	-	1	2	-	1	16
180	1	-	-	-	-	1	-	3	-	2	16
184	1	-	-	-	-	-	-	1	-	1	4
188	4	-	-	-	-	-	-	-	-	-	4
192	-	-	-	-	-	-	-	-	-	-	2
196	-	-	-	-	-	-	-	1	-	-	3
200	1	-	-	-	-	-	-	-	-	-	2
204	-	-	-	-	-	-	-	-	-	-	2
208	-	-	-	-	-	-	-	-	-	-	-
212	-	-	-	-	-	1	-	-	-	-	1
216	-	-	-	-	-	-	-	-	-	-	-
220	-	-	-	-	-	-	-	-	-	-	1
224	-	-	-	-	-	-	-	-	-	-	1
228	-	-	-	-	-	-	-	-	-	-	-
232	-	-	-	-	-	-	-	-	-	-	-
236	-	-	-	-	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	-
244	-	-	-	-	-	-	-	-	-	-	-
248	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-	-	1
TOTALS	939	72	15	83	2	5096	71	40	77	29	3614

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	JUNE, 1938							JULY, 1938						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	1	-	-	6	-	-	-	-	-	-	-
44	-	-	-	3	-	-	65	-	-	-	-	-	-	-
48	-	-	-	3	-	-	31	-	-	-	-	-	-	-
52	-	-	-	1	-	-	10	-	-	-	-	-	-	-
56	-	-	-	2	-	-	17	-	-	-	-	-	-	5
60	1	-	-	3	-	-	28	2	-	-	1	-	-	24
64	2	-	-	6	-	-	38	4	-	-	4	-	-	103
68	2	-	-	9	-	-	36	4	-	-	6	-	-	156
72	1	-	-	9	-	-	27	4	-	-	6	-	-	151
76	-	-	-	10	-	-	31	7	-	-	7	-	-	141
80	-	-	-	7	-	-	103	9	-	-	12	-	-	184
84	-	-	-	4	-	-	92	4	-	-	14	-	-	134
88	-	-	-	5	-	-	29	5	-	-	17	-	-	156
92	-	-	-	3	-	-	5	1	-	-	8	-	-	105
96	-	-	-	2	-	-	2	1	-	-	5	-	-	64
100	-	-	-	-	-	-	2	2	-	-	1	-	-	35
104	-	-	-	2	-	-	1	-	-	-	1	-	-	11
108	-	-	-	-	-	-	-	1	-	-	-	-	-	3
112	-	-	-	-	-	-	-	-	-	-	1	-	-	8
116	-	1	-	-	-	-	1	-	-	-	1	-	-	2
120	-	-	-	-	4	-	14	-	-	-	-	-	-	5
124	-	2	-	-	5	-	72	-	-	-	-	-	-	7
128	-	9	-	-	7	-	272	-	-	-	-	-	-	47
132	-	10	-	-	11	-	556	-	2	-	-	4	-	197
136	-	8	-	-	10	-	778	-	4	-	-	4	-	337
140	-	12	-	-	11	-	791	-	2	-	-	5	-	578
144	-	10	-	-	8	1	651	-	15	1	-	12	-	517
148	-	10	-	-	4	-	477	-	6	-	-	10	-	403
152	-	12	1	-	4	2	362	-	11	-	-	6	-	270
156	-	15	6	-	3	3	240	-	6	-	-	2	-	216
160	-	12	4	-	1	1	180	-	8	1	-	4	2	149
164	-	6	12	-	-	3	87	-	9	-	-	4	4	111
168	-	-	11	-	-	-	46	-	6	2	-	-	2	64
172	-	1	14	-	-	-	28	-	1	3	-	-	3	31
176	-	-	6	-	-	-	16	-	-	4	-	-	3	30
180	-	-	5	-	-	1	11	-	-	-	-	-	1	14
184	-	-	4	-	-	1	8	-	-	1	-	-	1	11
188	-	-	1	-	-	-	3	-	-	-	-	-	1	8
192	-	-	1	-	-	-	3	-	-	-	-	-	1	2
196	-	-	-	-	-	-	2	-	-	1	-	1	1	5
200	-	-	-	-	-	-	2	-	-	1	-	-	2	1
204	-	-	-	-	-	-	2	-	-	-	-	-	-	3
208	-	-	-	-	-	-	3	-	-	-	-	-	-	2
212	-	-	-	-	-	-	3	-	-	-	-	-	-	2
216	-	-	-	-	-	-	3	-	-	-	-	-	-	1
220	-	-	-	-	-	-	1	-	-	-	-	-	-	-
224	-	-	-	-	-	-	1	-	-	-	-	-	-	-
228	-	-	-	-	-	-	1	-	-	-	-	-	-	-
232	-	-	-	-	-	-	-	-	-	-	-	-	-	-
236	-	-	-	-	-	-	2	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	-	-	-	-
244	-	-	-	-	-	-	1	-	-	-	-	-	-	-
248	-	-	-	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	1	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTALS	6	108	65	70	68	12	5141	44	70	14	84	52	21	4293

TABLE VI(Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	AUGUST, 1938							SEPTEMBER, 1938						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
52	1	-	-	-	-	-	1	-	-	-	-	-	-	-
56	-	-	-	-	-	-	1	-	-	-	-	-	-	-
60	1	-	-	-	-	-	5	-	-	-	-	-	-	-
64	4	-	-	4	-	-	47	-	-	-	-	-	-	-
68	7	-	-	6	-	-	202	-	-	-	1	-	-	16
72	19	-	-	16	-	-	304	-	-	-	2	-	-	75
76	14	-	-	29	-	-	284	3	-	-	5	-	-	242
80	10	-	-	20	-	-	118	5	-	-	12	-	-	287
84	3	-	-	2	-	-	34	10	-	-	13	-	-	242
88	3	-	-	1	-	-	10	8	-	-	10	-	-	187
92	3	-	-	-	-	-	9	11	-	-	14	-	-	210
96	1	-	-	1	-	-	8	5	-	-	14	-	-	211
100	6	-	-	-	-	-	7	14	-	-	15	-	-	76
104	1	-	-	1	-	-	9	7	-	-	7	-	-	18
108	-	-	-	-	-	-	1	1	-	-	2	-	-	5
112	1	-	-	-	-	-	3	-	-	-	-	-	-	3
116	-	1	-	-	-	-	2	-	-	-	-	-	-	4
120	-	-	-	-	-	-	2	1	-	-	1	-	-	2
124	-	-	-	-	-	-	3	-	-	-	-	-	-	4
128	-	2	-	-	-	-	9	-	-	-	-	-	-	24
132	-	6	-	-	1	-	67	-	-	-	-	-	-	104
136	-	16	-	-	7	-	238	-	2	-	-	1	-	288
140	-	24	1	-	13	-	476	-	4	-	-	6	-	489
144	-	23	2	-	20	-	630	-	9	-	-	10	-	686
148	-	25	-	-	18	-	678	-	14	1	-	13	-	671
152	-	11	3	-	16	1	549	-	16	2	-	19	-	517
156	-	10	-	-	14	1	351	-	7	1	-	14	-	327
160	-	5	-	-	10	2	174	-	6	-	-	11	-	175
164	-	2	1	-	2	1	107	-	-	-	-	3	-	74
168	-	3	-	-	1	1	70	-	-	-	-	1	2	91
172	-	1	1	-	1	1	49	-	-	3	-	1	2	68
176	-	1	1	-	-	2	50	-	-	-	-	-	-	59
180	-	-	2	-	-	1	47	-	-	-	-	-	-	49
184	-	-	2	-	-	2	33	-	-	-	-	-	-	19
188	-	-	-	-	-	1	28	-	-	-	-	-	-	16
192	-	-	1	-	-	-	29	-	-	-	-	-	-	8
196	-	-	-	-	-	1	10	-	-	-	-	-	-	2
200	-	-	-	-	-	1	11	-	-	-	-	-	-	1
204	-	-	-	-	-	-	18	-	-	-	-	-	-	2
208	-	-	-	-	-	-	5	-	-	-	-	-	-	1
212	-	-	-	-	-	-	11	-	-	-	-	-	-	1
216	-	-	-	-	-	-	7	-	-	-	-	-	-	1
220	-	-	-	-	-	-	3	-	-	-	-	-	-	-
224	-	-	-	-	-	-	2	-	-	-	-	-	-	-
228	-	-	-	-	-	-	-	-	-	-	-	-	-	1
232	-	-	-	-	-	-	-	-	-	-	-	-	-	1
236	-	-	-	-	-	-	1	-	-	-	-	-	-	-
TOTALS	74	129	14	80	103	15	4703	65	58	7	96	79	4	5257

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	OCTOBER, 1938							NOVEMBER, 1938						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
60	-	-	-	-	-	-	1	-	-	-	-	-	-	-
64	-	-	-	-	-	-	14	-	-	-	-	-	-	-
68	-	-	-	-	-	-	34	-	-	-	-	-	-	-
72	-	-	-	-	-	-	17	-	-	-	-	-	-	-
76	1	-	-	2	-	-	55	-	-	-	-	-	-	-
80	8	-	-	5	-	-	212	-	-	-	-	-	-	13
84	14	-	-	5	-	-	350	2	-	-	3	-	-	40
88	13	-	-	9	-	-	262	3	-	-	4	-	-	112
92	5	-	-	6	-	-	222	5	-	-	9	-	-	180
96	1	-	-	7	-	-	344	5	-	-	9	-	-	262
100	2	-	-	6	-	-	277	1	-	-	4	-	-	154
104	7	-	-	5	-	-	202	-	-	-	3	-	-	111
108	5	-	-	6	-	-	95	2	-	-	2	-	-	143
112	3	-	-	-	-	-	85	4	-	-	3	-	-	127
116	2	-	-	1	-	-	94	5	-	-	4	-	-	107
120	3	-	-	2	-	-	95	5	-	-	5	-	-	55
124	2	-	-	-	-	-	72	6	1	-	5	-	-	37
128	2	1	-	1	-	-	62	-	-	-	-	-	-	31
132	-	1	-	-	-	-	55	1	1	-	2	-	-	24
136	-	3	-	-	-	-	166	1	-	-	-	-	-	16
140	1	10	-	-	1	-	363	1	-	-	-	-	-	22
144	-	4	-	-	2	-	494	-	2	-	-	-	-	78
148	-	11	-	-	4	-	469	-	6	-	-	-	-	198
152	-	22	1	1	17	-	473	1	7	-	-	2	-	416
156	-	19	1	-	22	-	390	-	8	1	-	-	-	760
160	-	16	3	-	20	1	218	-	6	-	-	13	-	800
164	-	6	1	-	12	1	125	-	11	-	-	13	-	670
168	-	3	1	-	3	1	65	-	8	1	-	13	1	548
172	-	1	3	-	2	-	37	-	2	1	-	8	-	480
176	-	1	1	-	1	-	55	-	7	5	-	5	6	397
180	-	-	-	-	1	-	80	-	2	4	-	3	4	283
184	-	-	-	-	-	2	81	-	2	4	-	-	7	211
188	-	-	-	-	1	2	86	-	-	6	-	-	6	147
192	-	-	-	-	-	2	70	-	-	3	-	-	2	82
196	-	-	-	-	-	4	50	-	-	3	-	-	2	64
200	-	-	-	-	-	2	35	-	-	2	-	-	1	59
204	-	-	-	-	-	1	20	-	-	1	-	-	2	46
208	-	-	-	-	-	-	17	-	-	1	-	-	-	38
212	-	-	-	-	-	-	6	-	-	-	-	-	-	32
216	-	-	-	-	-	-	6	-	-	1	-	-	-	35
220	-	-	-	-	-	-	6	-	-	2	-	-	-	16
224	-	-	-	-	-	-	-	-	-	-	-	-	-	8
228	-	-	-	-	-	-	-	-	-	-	-	-	-	2
232	-	-	-	-	-	-	1	-	-	-	-	-	-	2
236	-	-	-	-	-	-	1	-	-	-	-	-	-	2
240	-	-	-	-	-	-	-	-	-	-	-	-	-	1
244	-	-	-	-	-	-	-	-	-	-	-	-	-	1
248	-	-	-	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	-	-	-	-	-	-	-	1
256	-	-	-	-	-	-	-	-	-	-	-	-	-	-
260	-	-	-	-	-	-	-	-	-	-	-	-	-	-
264	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TOTALS	69	98	11	56	86	16	5862	42	63	35	53	57	31	6812

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	DECEMBER, 1938							JANUARY, 1939						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
68	-	-	-	-	-	-	-	1	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-	-	1
76	-	-	-	-	-	-	-	-	-	-	-	-	-	1
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	3	1	-	-	-	-	-	6
88	-	-	-	-	-	-	27	4	-	-	1	-	-	34
92	4	-	-	2	-	-	115	6	-	-	2	-	-	121
96	17	-	-	6	-	-	200	5	-	-	3	-	-	155
100	16	-	-	5	-	-	166	3	-	-	6	-	-	129
104	4	-	-	1	-	-	113	2	-	-	10	-	-	164
108	4	-	-	-	-	-	114	3	-	-	9	-	-	158
112	3	-	-	2	-	-	104	7	-	-	1	-	-	199
116	-	-	-	5	-	-	89	7	-	-	4	-	-	333
120	1	-	-	1	-	-	75	8	-	-	9	-	-	390
124	1	-	-	6	-	-	53	4	-	-	2	-	-	273
128	-	-	-	2	-	-	33	2	1	-	2	-	-	160
132	-	-	-	-	-	-	19	-	-	-	1	-	-	81
136	-	-	-	-	-	-	14	4	-	-	-	-	-	53
140	-	-	-	1	-	-	17	-	1	-	-	1	-	39
144	-	-	-	-	1	-	30	1	1	-	-	1	-	96
148	-	1	-	-	-	-	65	-	3	-	-	2	-	187
152	-	3	-	-	3	-	148	1	19	-	-	2	-	350
156	-	5	-	-	4	-	328	-	19	2	-	7	-	550
160	-	11	-	-	16	-	438	-	28	-	-	10	1	684
164	-	6	3	-	8	1	490	-	18	1	-	11	-	639
168	-	6	2	-	12	-	394	-	2	1	-	13	7	392
172	-	9	2	-	14	4	346	-	3	-	-	10	3	230
176	-	8	8	-	5	8	247	-	-	-	-	6	1	129
180	-	8	7	-	3	5	157	-	-	2	-	-	4	88
184	-	3	1	-	3	1	114	-	-	1	-	-	4	67
188	-	1	2	-	-	2	96	-	3	1	-	1	1	72
192	-	1	1	-	-	1	93	-	-	1	-	-	4	64
196	-	-	1	-	-	-	77	-	1	2	-	-	-	44
200	-	-	1	-	-	-	61	-	-	-	-	-	-	33
204	-	-	-	-	-	-	48	-	-	2	-	-	1	28
208	-	-	-	-	-	-	46	-	-	-	-	-	-	21
212	-	-	-	-	-	-	36	-	-	-	-	-	-	10
216	-	-	-	-	-	-	22	-	-	-	-	-	-	14
220	-	-	-	-	-	-	8	-	-	-	-	-	-	6
224	-	-	-	-	-	-	15	-	-	-	-	-	-	7
228	-	-	-	-	-	-	6	-	-	-	-	-	-	6
232	-	-	-	-	-	-	5	-	-	-	-	-	-	2
236	-	-	-	-	-	-	3	-	-	-	-	-	-	1
240	-	-	-	-	-	-	1	-	-	-	-	-	-	-
244	-	-	-	-	-	-	1	-	-	-	-	-	-	-
248	-	-	-	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-	-	-	-	-	-
260	-	-	-	-	-	-	-	-	-	-	-	-	-	-
264	-	-	-	-	-	-	-	-	-	-	-	-	-	-
268	-	-	-	-	-	-	-	-	-	-	-	-	-	-
272	-	-	-	-	-	-	1	-	-	-	-	-	-	-
TOTALS	50	62	28	31	69	22	4418	59	99	13	50	64	26	6017

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	FEBRUARY, 1939							MARCH, 1939						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
76	-	-	-	-	-	-	1	-	-	-	-	-	-	-
80	-	-	-	-	-	-	7	-	-	-	-	-	-	7
84	-	-	-	-	-	-	7	1	-	-	1	-	-	39
88	1	-	-	1	-	-	16	4	-	-	4	-	-	103
92	3	-	-	4	-	-	96	4	-	-	5	-	-	244
96	19	-	-	18	-	-	279	7	-	-	6	-	-	496
100	11	-	-	13	-	-	354	2	-	-	7	-	-	641
104	5	-	-	2	-	-	209	2	-	-	4	-	-	427
108	6	-	-	1	-	-	125	6	-	-	5	-	-	427
112	4	-	-	-	-	-	70	9	-	-	9	-	-	546
116	-	-	-	-	-	-	63	12	-	-	4	-	-	574
120	5	-	-	4	-	-	80	29	-	-	15	-	-	575
124	5	-	-	3	-	-	66	32	-	-	12	-	-	539
128	6	-	-	3	-	-	62	22	-	-	7	-	-	496
132	3	1	-	-	-	-	86	9	-	-	6	-	-	340
136	1	-	-	1	1	-	89	5	-	-	5	-	-	271
140	3	4	-	3	3	-	105	7	-	-	7	1	-	201
144	3	2	-	-	2	-	109	1	-	-	4	1	-	184
148	-	8	1	-	4	-	108	-	2	-	9	-	-	125
152	1	10	-	-	6	-	136	-	1	-	5	-	-	76
156	-	12	-	1	8	-	213	-	1	-	2	1	-	49
160	-	21	1	-	10	-	282	-	3	-	-	1	-	50
164	-	17	4	-	8	-	236	-	7	1	-	1	-	69
168	-	19	3	-	3	-	132	-	13	1	-	3	1	129
172	-	12	3	-	2	-	96	-	27	5	-	7	-	179
176	-	8	2	-	-	-	93	-	35	4	-	5	2	223
180	-	7	5	-	1	-	122	-	40	11	-	12	7	246
184	-	9	3	-	1	2	136	-	29	12	-	4	14	228
188	-	1	2	-	-	4	117	-	15	18	-	5	11	170
192	-	1	6	-	-	4	106	-	4	12	-	-	10	95
196	-	-	1	-	-	4	86	-	3	8	-	-	6	68
200	-	-	2	-	-	2	51	-	-	8	-	-	4	35
204	-	-	-	-	-	1	35	-	-	5	-	-	2	17
208	-	-	-	-	-	2	30	-	-	1	-	-	2	6
212	-	-	-	-	-	-	18	-	-	-	-	-	-	2
216	-	-	-	-	-	1	15	-	-	-	-	-	-	1
220	-	-	-	-	-	-	6	-	-	-	-	-	-	-
224	-	-	-	-	-	-	3	-	-	-	-	-	-	-
228	-	-	-	-	-	-	3	-	-	-	-	-	-	-
232	-	-	-	-	-	-	-	-	-	-	-	-	-	-
236	-	-	-	-	-	-	1	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	-	-	-	-
244	-	-	-	-	-	-	1	-	-	-	-	-	-	-
248	-	-	-	-	-	-	-	-	-	-	-	-	-	1
252	-	-	-	-	-	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTALS	76	132	33	54	49	20	3850	152	180	86	117	41	59	7879

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	APRIL, 1939							MAY, 1939						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
92	-	-	-	-	-	-	1	-	-	-	-	-	-	-
96	1	-	-	-	-	-	5	-	-	-	-	-	-	-
100	1	-	-	-	-	-	14	-	-	-	-	-	-	2
104	4	-	-	-	-	-	70	-	-	-	-	-	-	14
108	8	-	-	8	-	-	185	-	-	-	-	-	-	32
112	19	-	-	12	-	-	321	1	-	-	1	-	-	81
116	32	-	-	11	-	-	317	10	-	-	6	-	-	168
120	26	-	-	12	-	-	240	28	-	-	13	-	-	277
124	36	-	-	16	-	-	194	19	-	-	7	-	-	233
128	24	-	-	8	-	-	144	7	-	-	2	-	-	177
132	16	-	-	6	-	-	84	3	-	-	-	-	-	111
136	11	1	-	3	-	-	83	3	-	-	1	-	-	62
140	13	1	-	4	-	-	56	1	-	-	-	-	-	39
144	6	-	-	1	-	-	28	-	-	-	-	-	-	29
148	2	1	-	-	-	-	26	-	-	-	-	-	-	22
152	1	2	-	1	2	-	36	4	2	-	2	2	-	33
156	1	5	-	1	1	-	57	-	2	-	-	-	-	34
160	-	6	-	-	6	-	80	1	1	1	2	-	-	34
164	-	13	1	-	2	1	147	-	4	1	1	1	-	40
168	-	18	-	-	8	-	177	-	11	2	-	10	1	54
172	-	23	-	-	9	-	213	-	7	-	-	7	-	61
176	-	12	3	-	18	2	210	-	11	2	-	15	2	104
180	-	14	3	-	5	-	123	-	20	2	-	18	7	179
184	-	9	1	-	4	-	61	-	14	2	-	7	4	115
188	-	1	-	-	-	-	20	-	12	3	-	9	6	99
192	-	1	-	-	-	-	14	-	6	2	-	4	5	51
196	-	1	1	-	-	-	13	-	1	1	-	2	3	19
200	-	-	-	-	-	-	6	-	2	6	-	-	3	17
204	-	-	-	-	-	-	5	-	1	2	-	1	2	7
208	-	-	-	-	-	1	12	-	-	3	-	-	1	6
212	-	-	-	-	-	-	3	-	-	3	-	-	1	3
216	-	-	-	-	-	-	6	-	-	-	-	-	-	-
220	-	-	-	-	-	-	-	-	1	-	-	-	-	2
224	-	-	-	-	-	-	1	-	-	-	-	-	-	-
228	-	-	-	-	-	-	2	-	-	-	-	-	-	-
232	-	-	-	-	-	-	-	-	-	-	-	-	-	-
236	-	-	-	-	-	-	1	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	-	-	-	1
244	-	-	-	-	-	-	1	-	-	-	-	-	-	-
248	-	-	-	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	1	-	-	-	-	-	-	-
TOTALS	201	108	9	83	55	4	2957	77	95	30	35	76	35	2106

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	JUNE, 1939							JULY, 1939						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
124	-	-	-	-	-	-	1	-	-	-	-	-	-	-
128	1	-	-	1	-	-	17	-	-	-	-	-	-	-
132	2	-	-	1	-	-	48	-	-	-	-	-	-	-
136	5	-	-	3	-	-	114	-	-	-	-	-	-	-
140	9	-	-	5	-	-	92	-	-	-	-	-	-	-
144	8	-	-	4	-	-	103	-	-	-	-	-	-	-
148	4	-	-	-	-	-	83	-	-	-	-	-	-	-
152	3	-	-	-	-	-	33	-	-	-	-	-	-	1
156	3	-	-	1	-	-	51	-	-	-	-	-	-	2
160	9	-	-	2	-	-	26	-	-	-	-	1	-	1
164	1	1	-	-	-	1	11	-	-	-	-	-	-	-
168	1	-	-	-	-	-	12	-	-	-	-	-	-	1
172	-	3	-	-	1	1	14	-	1	-	-	1	-	6
176	-	6	-	-	4	-	25	1	3	-	-	1	-	3
180	-	3	-	-	1	-	24	-	1	-	-	-	-	2
184	-	7	1	-	5	3	24	-	2	-	-	-	-	15
188	-	2	1	-	2	2	22	-	12	2	-	5	-	14
192	-	4	2	-	4	3	22	-	10	3	-	3	-	35
196	-	3	4	-	5	2	16	-	21	4	-	5	4	49
200	-	4	4	-	7	2	17	-	12	11	-	7	3	59
204	-	4	2	-	2	5	6	-	12	23	-	14	11	54
208	-	3	5	-	3	5	10	-	5	20	-	4	18	48
212	-	-	9	-	-	10	6	-	3	14	-	-	11	21
216	-	-	-	-	-	-	3	-	-	8	-	-	7	16
220	-	-	2	-	-	2	-	-	-	2	-	-	2	10
224	-	-	-	-	-	-	-	-	-	1	-	-	-	5
228	-	-	-	-	-	-	-	-	-	-	-	-	-	1
232	-	-	-	-	-	-	-	-	-	-	-	-	-	2
236	-	-	-	-	-	-	-	-	-	-	-	-	-	1
240	-	-	-	-	-	-	-	-	-	-	-	-	-	1
244	-	-	-	-	-	-	-	-	-	-	-	-	-	2
248	-	-	-	-	-	-	-	-	-	-	-	-	-	1
252	-	-	-	-	-	-	-	-	-	-	-	-	-	1
256	-	-	-	-	-	-	-	-	-	-	-	-	-	3
260	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TOTALS	46	40	30	17	34	36	780	1	82	88	-	41	56	355

TABLE VI (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled in California, by Ages.

Fish length	AUGUST, 1939							SEPTEMBER, 1939						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
156	-	-	-	-	-	-	-	-	-	-	-	-	-	5
160	-	-	-	-	-	-	-	-	-	-	-	-	-	3
164	-	-	-	-	-	-	-	-	-	-	-	-	-	5
168	3	-	-	5	-	-	6	-	1	-	-	-	-	10
172	1	-	-	1	1	-	5	-	1	-	-	-	-	15
176	6	1	-	5	2	-	11	-	1	-	-	-	-	7
180	3	1	-	5	4	1	13	-	2	-	-	-	-	7
184	-	3	-	1	2	-	7	-	1	-	-	-	-	8
188	-	1	-	-	3	-	14	-	1	-	-	-	-	5
192	-	9	3	-	6	1	38	-	3	1	-	-	-	19
196	1	14	1	-	7	3	59	-	6	2	-	-	-	40
200	-	16	12	-	4	9	82	-	18	5	-	-	-	59
204	-	38	29	-	9	13	75	-	27	36	-	-	-	78
208	-	36	51	-	3	15	100	-	17	27	-	-	-	60
212	-	24	56	-	4	14	75	-	10	19	-	-	-	36
216	-	5	41	-	-	9	43	-	-	11	-	-	-	13
220	-	1	21	-	-	4	27	-	1	3	-	-	-	6
224	-	-	6	-	-	1	6	-	1	-	-	-	-	2
228	-	-	1	-	-	-	3	-	-	-	-	-	-	1
232	-	-	-	-	-	-	1	-	-	-	-	-	-	-
236	-	-	-	-	-	-	1	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	-	-	-	-
244	-	-	-	-	-	-	1	-	-	-	-	-	-	-
248	-	-	-	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTALS	14	149	221	17	45	70	567	-	90	104	-	-	-	379

Fish length	OCTOBER, 1939						
	Fish aged						Total fish measured
	From scales			From otoliths			
	Year classes						
	38	37	36	38	37	36	
172	-	-	-	-	-	-	3
176	-	-	-	-	-	-	2
180	-	-	-	-	-	-	5
184	-	-	-	-	-	-	3
188	-	-	-	-	-	-	8
192	-	-	-	-	-	-	4
196	-	-	-	-	-	-	25
200	-	8	2	-	-	-	38
204	-	23	9	-	-	-	51
208	-	4	9	-	-	-	23
212	-	4	7	-	-	-	19
216	-	4	3	-	-	-	13
220	-	-	4	-	-	-	4
TOTALS	-	43	34	-	-	-	198

TABLE VII.-Frequency Record of Juvenile Pilchards Sampled Outside California, by Ports and by Ages.

Fish length	JULY, 1938 Southern Lower California							AUGUST, 1938 Central Lower California						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
64	-	-	-	-	-	-	-	1	-	-	-	-	-	1
68	-	-	-	-	-	-	1	2	-	-	1	-	-	10
72	-	-	-	-	-	-	25	3	-	-	4	-	-	15
76	-	-	-	-	-	-	68	2	-	-	10	-	-	55
80	-	-	-	1	-	-	271	7	-	-	4	-	-	41
84	-	-	-	5	-	-	404	6	-	-	8	-	-	32
88	1	-	-	8	-	-	244	5	-	-	1	-	-	10
92	1	-	-	4	-	-	140	1	-	-	-	-	-	3
96	3	-	-	1	-	-	84	-	-	-	1	-	-	4
100	4	-	-	1	-	-	57	4	-	-	4	-	-	14
104	3	-	-	4	-	-	58	5	-	-	8	-	-	28
108	5	-	-	7	-	-	63	7	-	-	11	-	-	26
112	10	-	-	7	-	-	77	6	-	-	6	-	-	14
116	11	-	-	6	-	-	73	3	-	-	2	-	-	8
120	10	-	-	1	-	-	62	1	1	-	2	-	-	3
124	9	1	-	1	-	-	35	-	-	-	-	-	-	-
128	2	-	-	-	-	-	20	-	-	-	-	-	-	-
132	3	-	-	-	-	-	8	-	-	-	-	-	-	-
136	-	-	-	-	-	-	2	-	-	-	-	-	-	-
140	-	-	-	-	-	-	2	-	-	-	-	-	-	-
144	-	-	-	-	-	-	-	-	-	-	-	-	-	-
148	-	-	-	-	-	-	-	-	-	-	-	-	-	-
152	-	-	-	-	-	-	-	-	-	-	-	-	-	-
156	-	-	-	-	-	-	-	-	-	-	-	-	-	-
160	-	-	-	-	-	-	-	-	-	-	-	-	-	-
164	-	-	-	-	-	-	-	-	-	-	-	-	-	-
168	-	-	-	-	-	-	-	-	-	-	-	-	-	-
172	-	-	-	-	-	-	-	-	-	-	-	-	-	-
176	-	-	-	-	-	1	-	-	-	-	-	-	-	-
180	-	-	-	-	-	-	-	-	-	-	-	-	-	-
184	-	-	-	-	-	-	-	-	-	-	-	-	-	-
188	-	-	-	-	-	-	-	-	-	-	-	-	-	-
192	-	-	-	-	-	-	-	-	-	-	-	-	-	-
196	-	-	1	-	-	-	-	-	-	-	-	-	-	-
TOTALS	62	1	1	46	-	1	1694	53	1	-	62	-	-	264

TABLE VII (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled Outside California, by Ports and by Ages.

Fish length	SEPTEMBER, 1938 Washington							OCTOBER, 1938 Washington						
	Fish aged						Total fish measured	Fish aged						Total fish measured
	From scales			From otoliths				From scales			From otoliths			
	Year classes							Year classes						
	38	37	36	38	37	36		38	37	36	38	37	36	
60	-	-	-	-	-	-	-	5	-	-	-	-	-	7
64	-	-	-	-	-	-	-	8	-	-	-	-	-	5
68	-	-	-	-	-	-	-	9	-	-	-	-	-	11
72	-	-	-	-	-	-	-	4	-	-	-	-	-	6
76	-	-	-	-	-	-	-	-	-	-	-	-	-	4
80	-	-	-	-	-	-	-	-	-	-	-	-	-	4
84	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88	-	-	-	-	-	-	-	-	-	-	-	-	-	-
92	-	-	-	-	-	-	-	-	1	-	-	-	-	2
96	-	-	-	-	-	-	-	1	2	-	-	-	-	2
100	-	-	-	-	-	-	-	-	2	-	-	-	-	2
104	-	-	-	-	-	-	1	-	1	-	-	-	-	1
108	-	-	-	-	-	-	2	1	-	-	-	-	-	1
112	-	2	-	-	-	-	5	-	2	-	-	-	-	2
116	-	-	-	-	-	-	3	-	2	-	-	-	-	1
120	-	3	-	-	-	-	10	-	-	-	-	-	-	1
124	-	5	-	-	-	-	15	-	-	-	-	-	-	-
128	-	2	-	-	-	-	4	-	-	-	-	-	-	-
132	-	3	-	-	-	-	17	-	-	-	-	-	-	-
136	-	1	-	-	-	-	8	-	-	-	-	-	-	-
140	-	3	-	-	-	-	10	-	-	-	-	-	-	-
144	-	1	1	-	-	-	6	-	-	-	-	-	-	-
148	-	2	-	-	-	-	7	-	-	-	-	-	-	1
152	-	-	-	-	-	-	3	-	-	-	-	-	-	-
156	-	-	-	-	-	-	1	-	-	-	-	-	-	-
160	-	-	-	-	-	-	-	-	-	-	-	-	-	-
164	-	-	-	-	-	-	1	-	-	-	-	-	-	-
168	-	-	-	-	-	-	2	-	-	-	-	-	-	-
172	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTALS	-	22	1	-	-	-	95	38	10	-	-	-	-	50

TABLE VII (Cont'd.).-Frequency Record of Juvenile Pilchards Sampled Outside California, by Ports and by Ages.

MAY, 1939

Oregon

Fish length	Fish aged: From scales (Year classes 38)	From scales (37)	From scales (36)	From otoliths (38)	From otoliths (37)	From otoliths (36)	Total fish measured
104	-	-	-	-	-	-	1
108	-	-	-	-	-	-	1
112	-	-	-	-	-	-	1
116	-	-	-	-	-	-	-
120	-	-	-	-	-	-	2
124	-	-	-	-	-	-	3
128	-	-	-	-	-	-	-
132	-	-	-	-	-	-	12
136	1	-	-	-	-	-	15
140	-	-	-	-	-	-	24
144	-	-	-	-	-	-	45
148	-	-	-	-	-	-	43
152	-	-	-	-	-	-	56
156	-	-	-	-	-	-	57
160	-	-	-	-	-	-	54
164	-	1	-	-	-	-	30
168	-	-	-	-	-	-	19
172	-	3	-	-	-	-	7
176	-	6	-	-	-	-	3
180	-	3	1	-	-	-	2
184	-	7	-	-	-	-	-
188	-	2	-	-	-	-	-
192	-	4	-	-	-	-	-
196	-	3	-	-	-	-	-
200	-	4	-	-	-	-	-
204	-	4	-	-	-	-	-
208	-	3	-	-	-	-	-
212	-	-	-	-	-	-	-
TOTALS	1	40	1	-	-	-	375

Table VIII. Statistics of length frequency curves for California pilchards found from scale studies to belong to year classes 1936 to 1938.

Date		Number of specimens	Mean body length	Standard error; mean	Standard deviation	Standard error; standard deviation
Year Class 1938						
1938	July	44	79.27	1.59	10.52	1.12
	August	74	78.69	1.30	11.22	0.92
	September	65	91.07	1.11	8.97	0.79
	October	69	94.66	1.81	15.06	1.28
	November	42	108.59	2.51	16.26	1.77
	December	50	98.94	0.90	6.35	0.63
1939	January	59	108.96	2.11	16.21	1.49
	February	76	109.05	1.86	16.24	1.32
	March	152	118.10	1.01	12.40	0.71
	April	201	122.25	0.73	10.35	0.52
	May	77	123.24	1.05	9.17	0.74
Year Class 1937						
1938	April	72	126.39	1.56	13.23	1.10
	May	71	143.44	1.59	13.37	1.12
	June	108	146.48	1.13	11.78	0.80
	July	70	153.01	1.18	9.87	0.83
	August	129	146.15	0.79	9.03	0.56
	September	58	148.33	0.76	5.78	0.54
	October	98	153.23	0.86	8.53	0.61
	November	63	161.66	1.45	11.53	1.03
	December	62	167.08	1.26	9.89	0.89
1939	January	99	157.62	0.89	8.90	0.63
	February	132	162.59	1.01	11.60	0.71
	March	180	176.01	0.62	8.35	0.44
	April	108	169.37	0.94	9.78	0.66
	May	95	177.60	1.10	10.74	0.78
	July	183	194.17	0.93	8.44	0.66
	August	150	202.55	0.60	7.35	0.42
	September	90	199.83	0.95	9.06	0.68
	October	43	204.15	0.67	4.41	0.48
Year Class 1936						
1938	April	15	149.63	2.21	8.56	1.56
	May	40	165.20	1.90	12.00	1.34
	June	65	168.02	1.05	8.46	0.74
	July	14	172.64	3.50	13.09	2.47
	August	14	165.93	4.57	17.09	3.23
	September	7	158.93	3.51	9.30	2.49
	October	11	163.32	1.98	6.95	1.48
	November	35	186.93	2.27	13.43	1.60
	December	28	178.78	1.69	8.92	1.19
1939	January	13	180.88	4.43	15.99	3.14
	February	33	177.72	2.21	12.70	1.56
	March	86	186.45	1.00	9.26	0.71
	April	9	177.52	2.82	8.47	2.00
	May	30	190.50	2.64	14.48	1.87
	July	91	205.41	0.73	6.93	0.52
	August	220	209.35	0.42	6.25	0.30
	September	102	206.28	0.53	5.33	0.37
	October	33	207.68	0.95	5.45	0.67

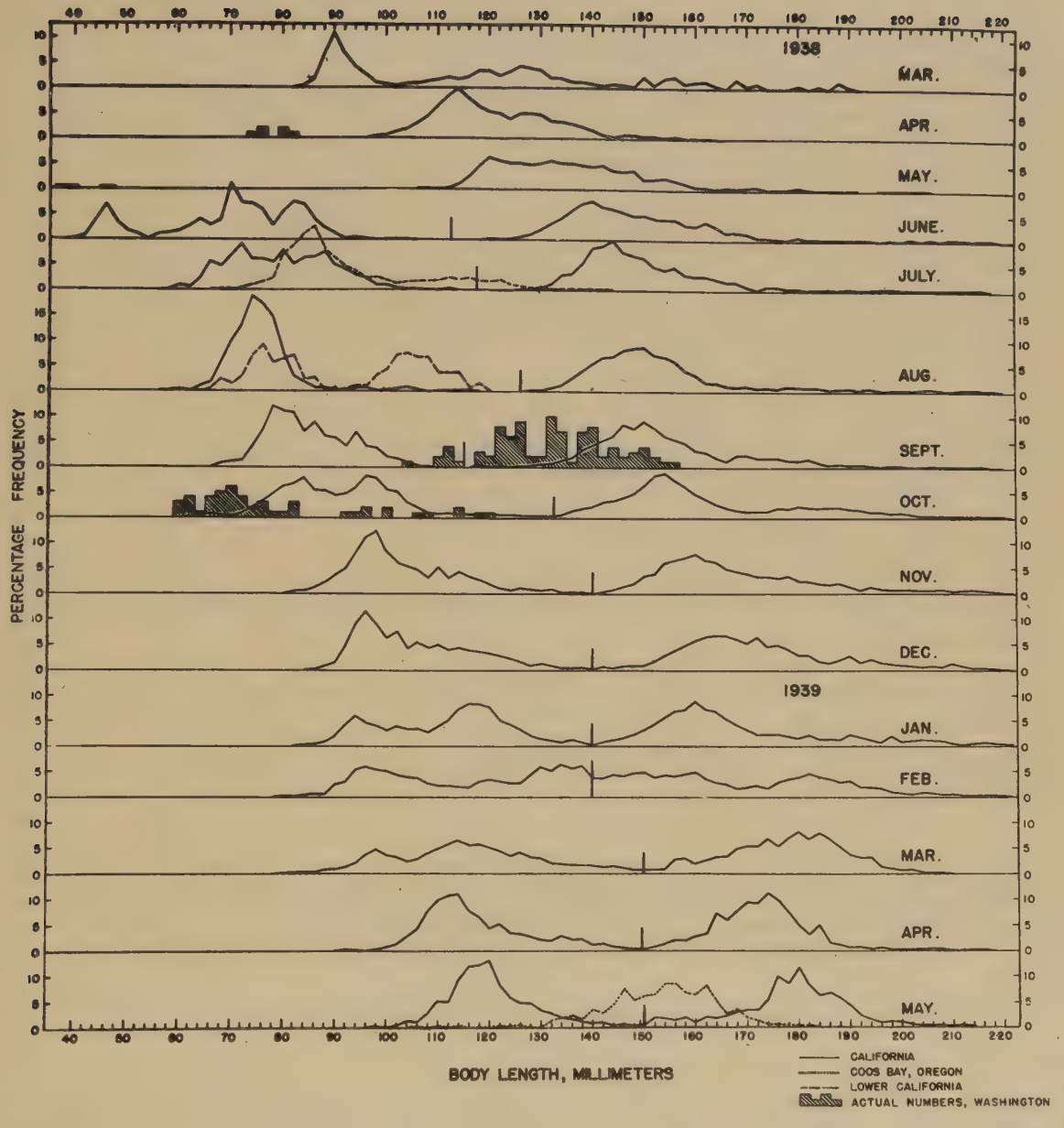

Figure 1. Frequency curves showing body lengths of pilchards sampled from the Pacific coast bait fisheries during 1938 and 1939. The samples are summarized by months.

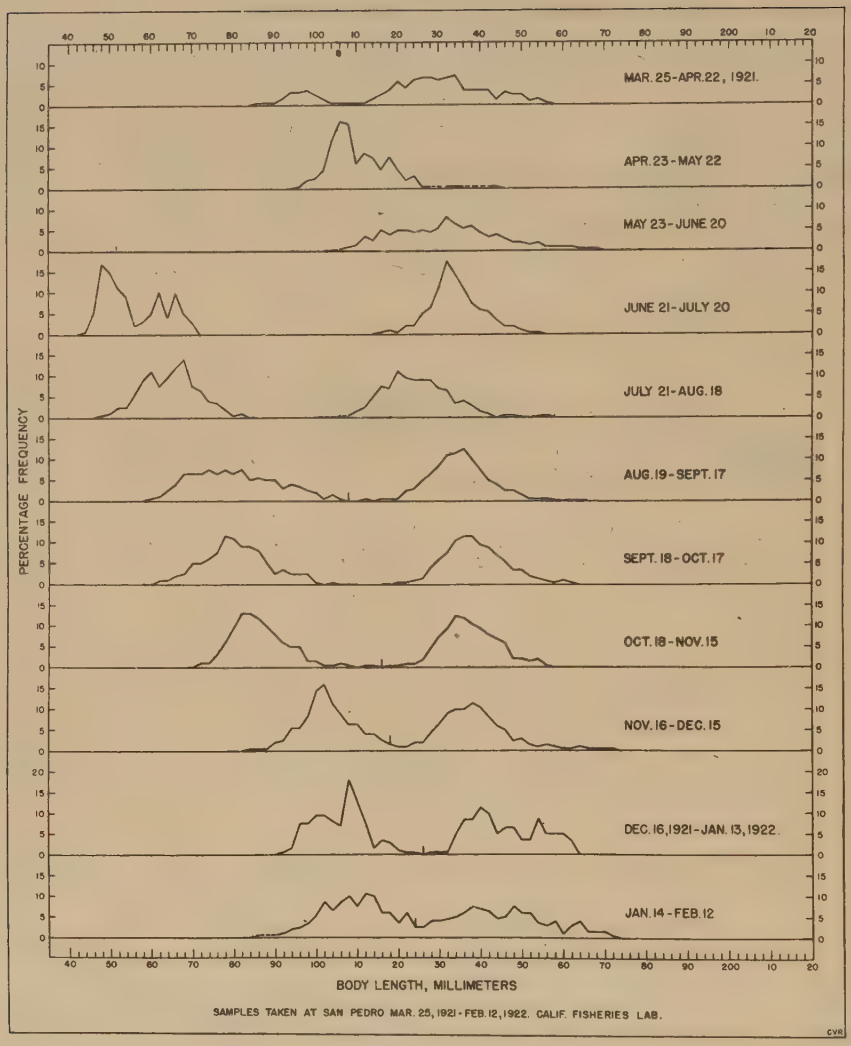

Figure 2. Frequency curves showing body lengths of pilchards sampled from bait fisheries of San Pedro from March, 1921, to February, 1922. The samples are summarized by lunar months. Original data furnished by California State Fisheries Laboratory, and discussed by Higgins (unpublished manuscript).

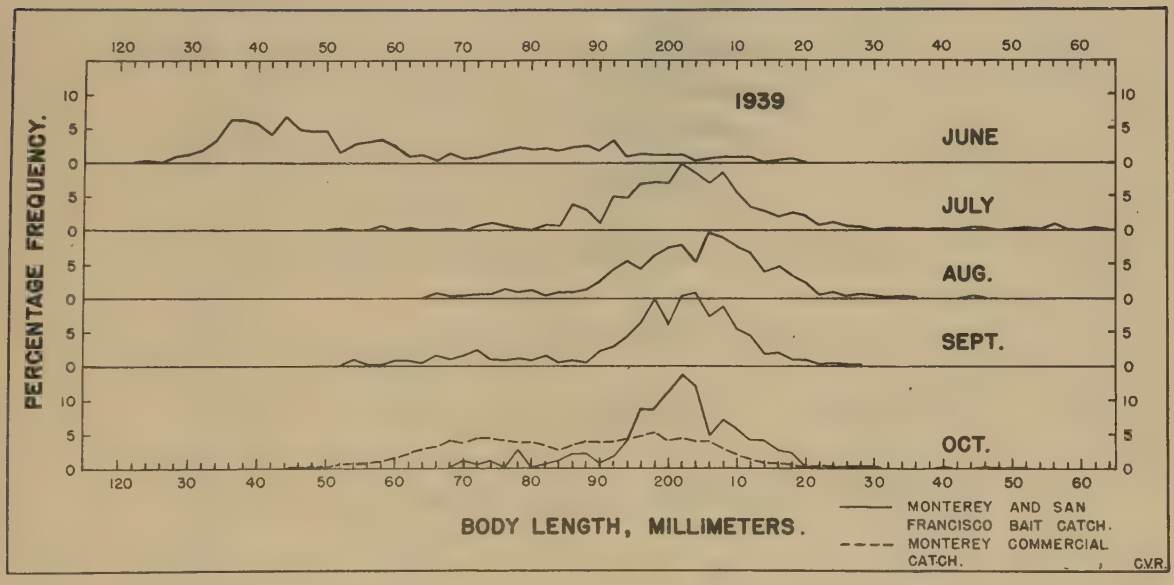

Figure 3. Frequency curves showing body lengths of pilchards sampled from central California bait fisheries, and, in October, from the Monterey commercial fishery for adults. The samples are summarized by months.

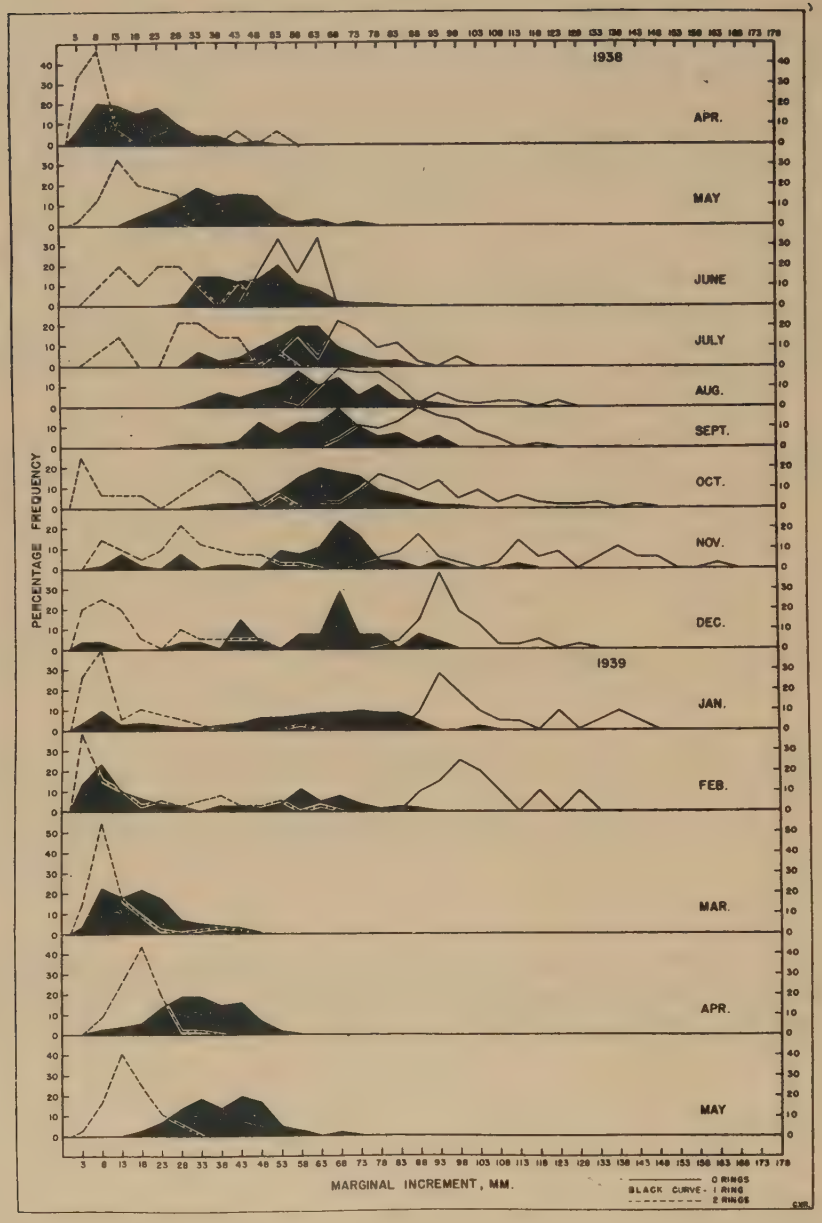

Figure 4. Frequencies of marginal increment widths in scales having 0, 1, and 2 rings. Dimensions are in millimeters of projected image; magnification is $43\frac{1}{2}$ diameters. The 32.5 mm. point is arbitrarily chosen as separating the narrow from the wide increments.

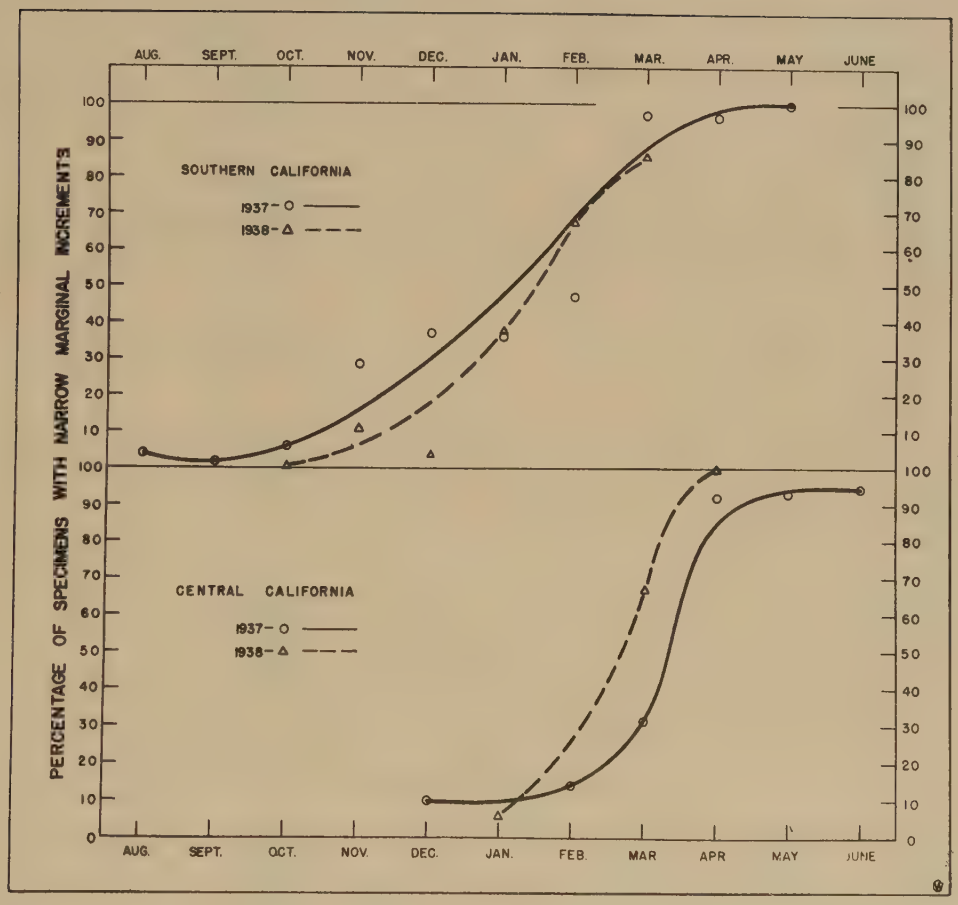

Figure 5. Percentage of scales having narrow marginal increments.

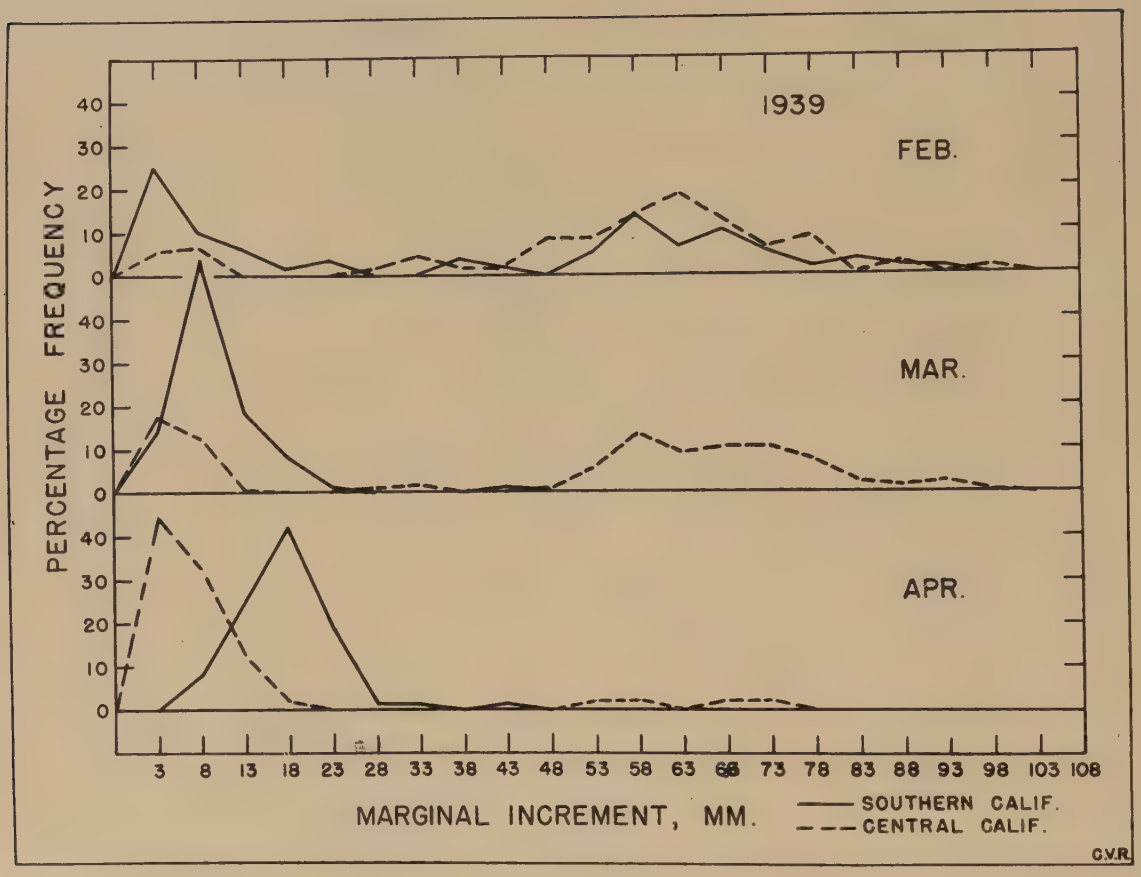

Figure 6. Comparing the widths of marginal increments in scales of fish from southern California with those from central California. Dimensions as in figure 5.

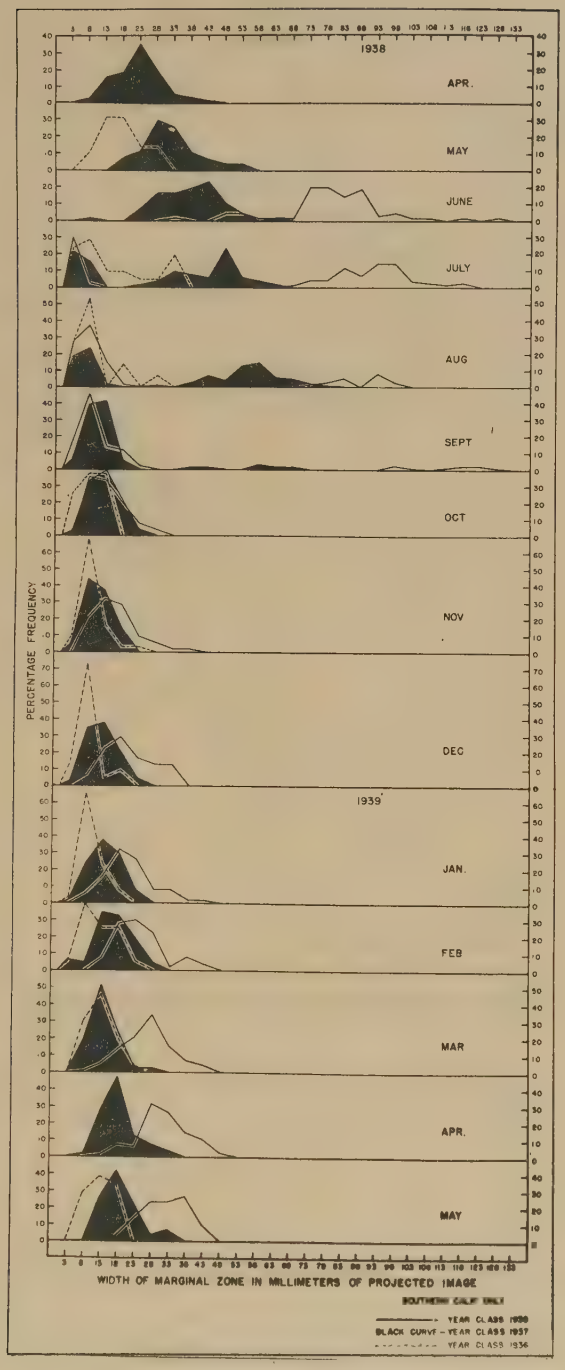

Figure 7. Frequencies of marginal increment widths in otoliths assigned to year classes 1936, 1937, 1938. Dimensions are in millimeters of projected image; the magnification is 125 diameters. The boundary between narrow and wide increments is taken as 35 mm. of projected image for specimens of year class 1938; 20 mm. for those of 1937; and 15 mm. for those of 1936.

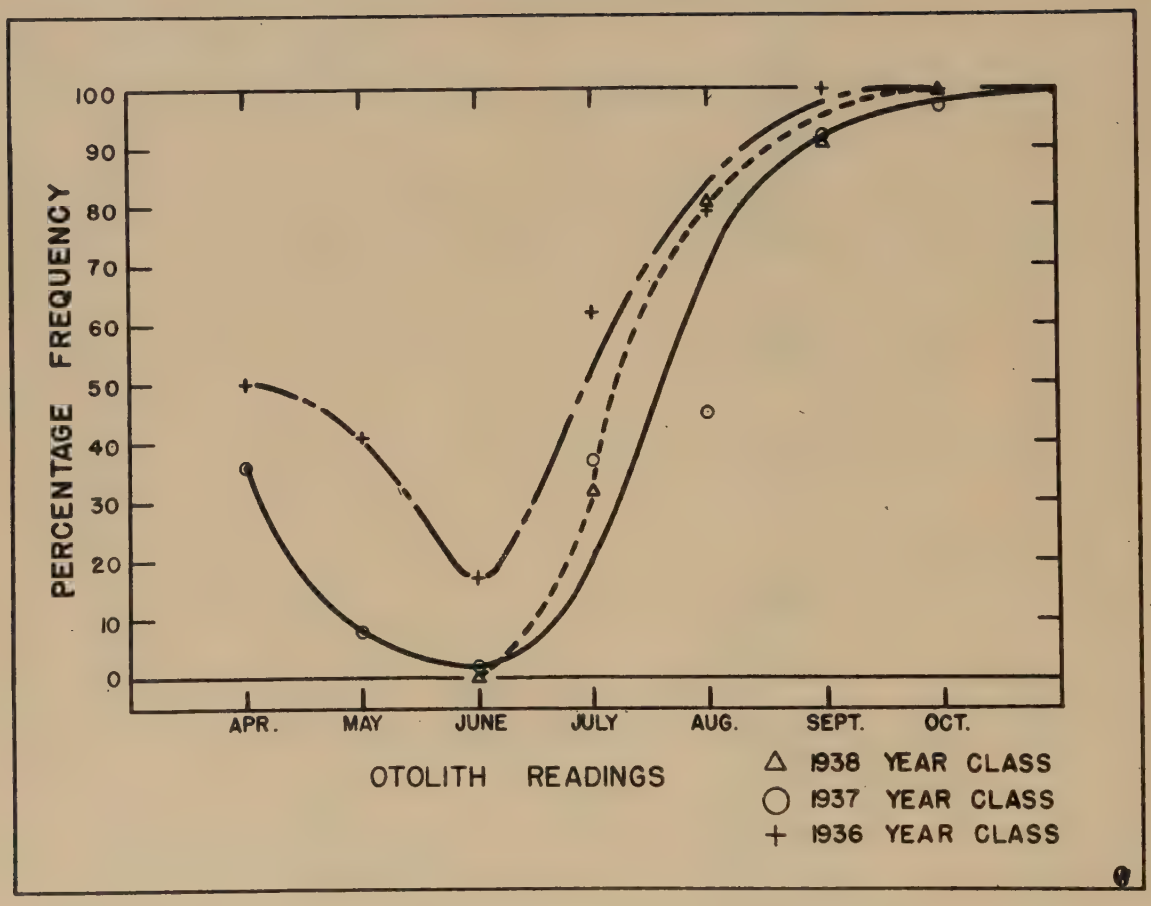

Figure 8. Percentage of otoliths with narrow marginal increments.

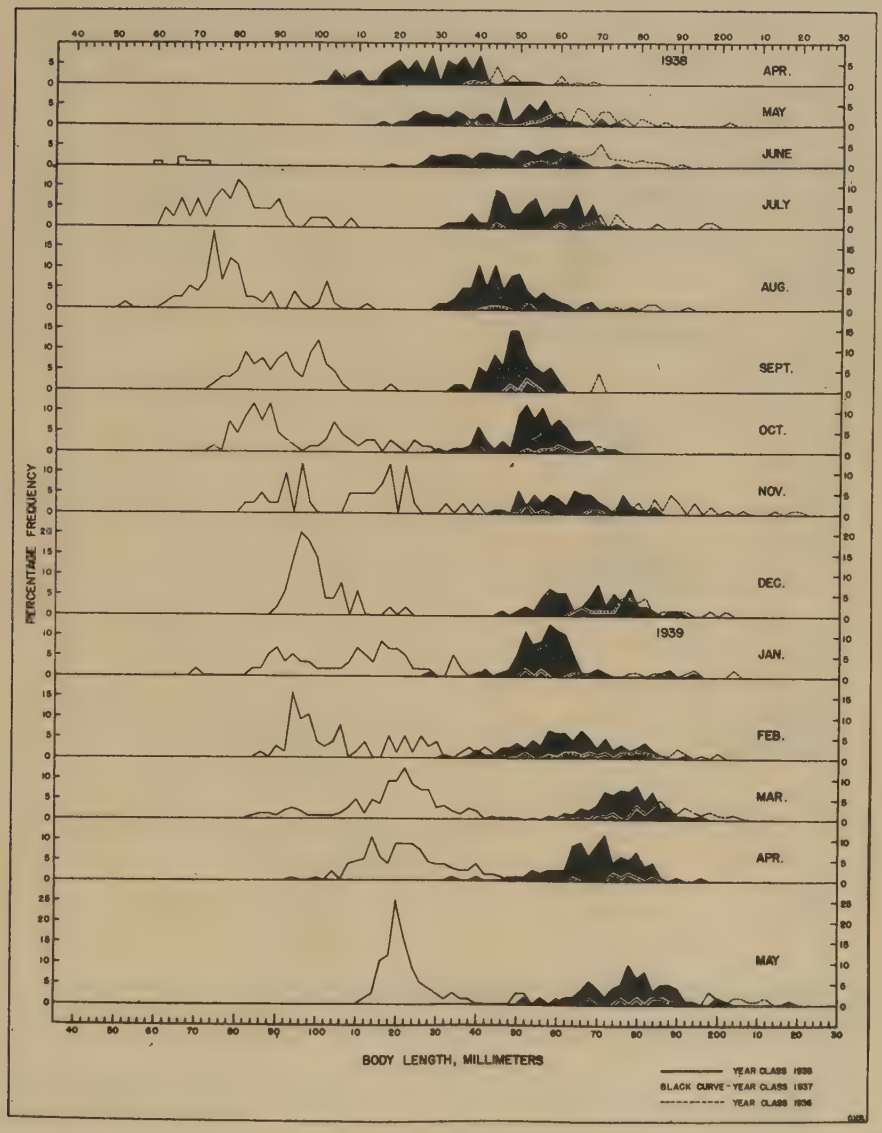

Figure 9. Showing the age composition (first three year classes only are given) of 2,600 specimens taken from California samples represented in figure 1. The ages were determined from scales.

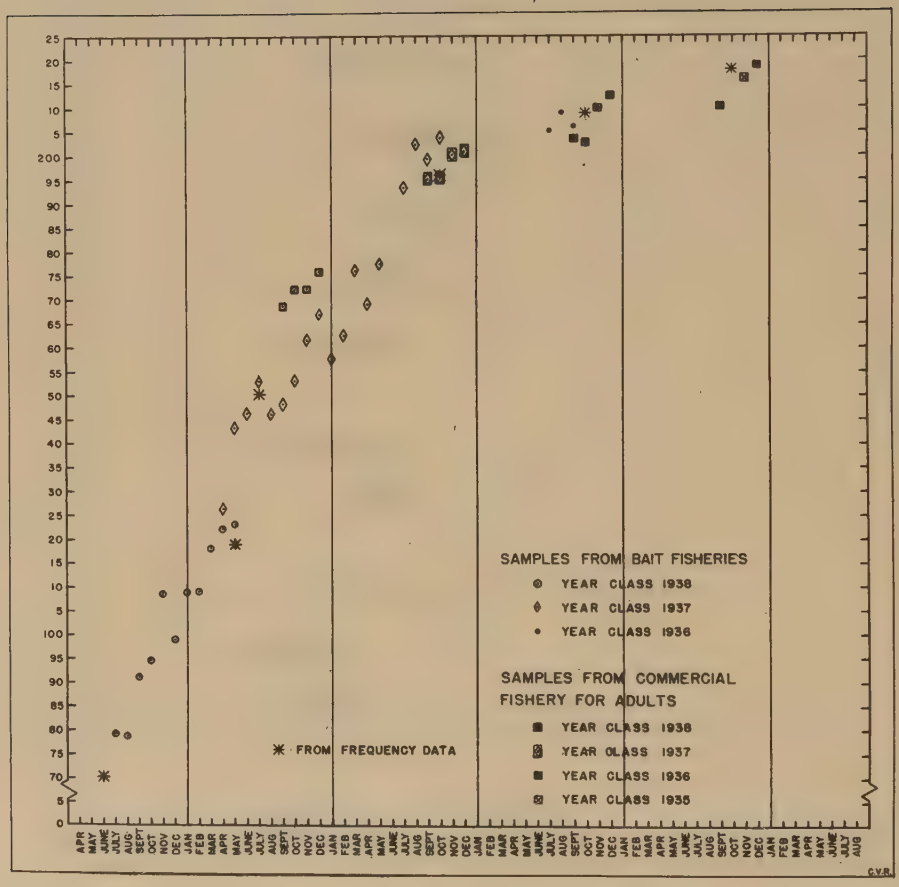

Figure 10. Mean body lengths of year classes 1935 to 1938 plotted according to age, and to time of capture. Ages were determined by scales; samples were from the California bait fisheries, or from commercial fishery for adults.

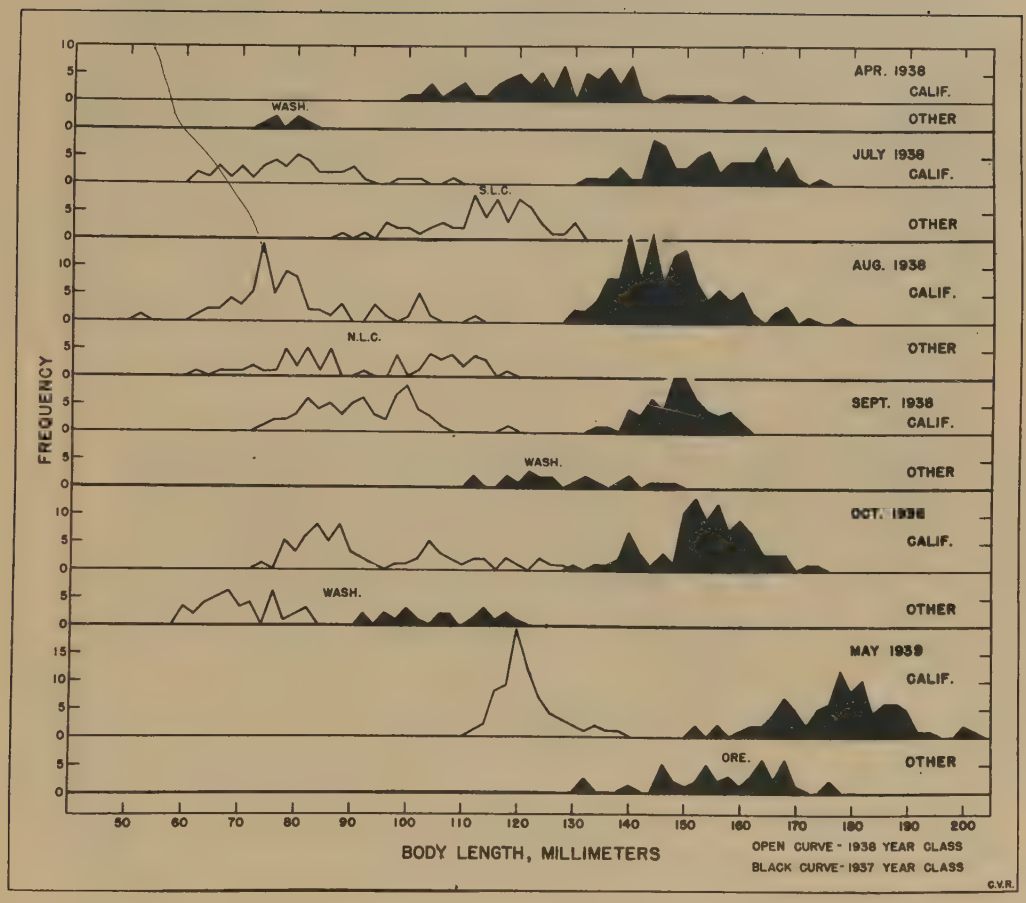

Figure 11. Comparing the body lengths of fish collected in California with those taken during the same months in Washington (Wash.), Oregon (Ore.), northern Lower California (N.L.C.) or southern Lower California (S.L.C.).

Figure 12. Above, pilchard scale with no annuli; body length of fish 63 mm.; caught June 22, 1938. Below, photomicrograph of a portion of a longitudinal section through a pilchard scale to show the surface folds.

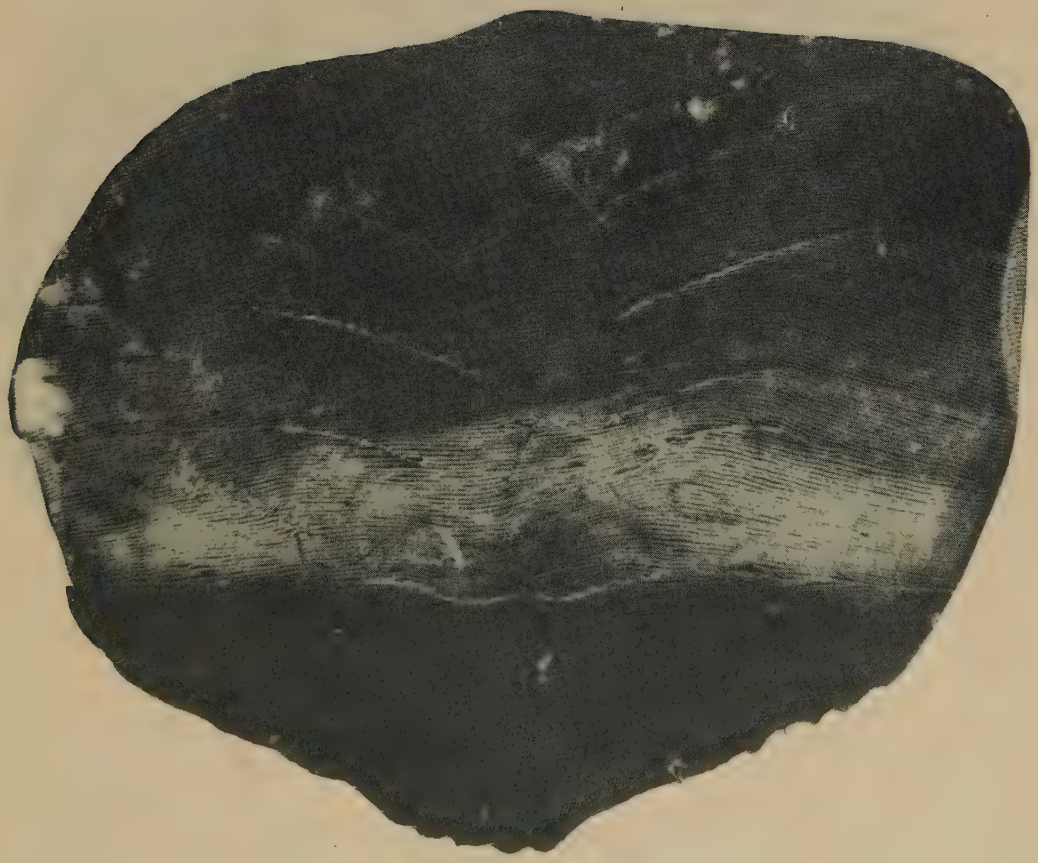

Figure 13. A pilchard scale with no annuli. Body length of fish 144 mm.; caught July 9, 1938.

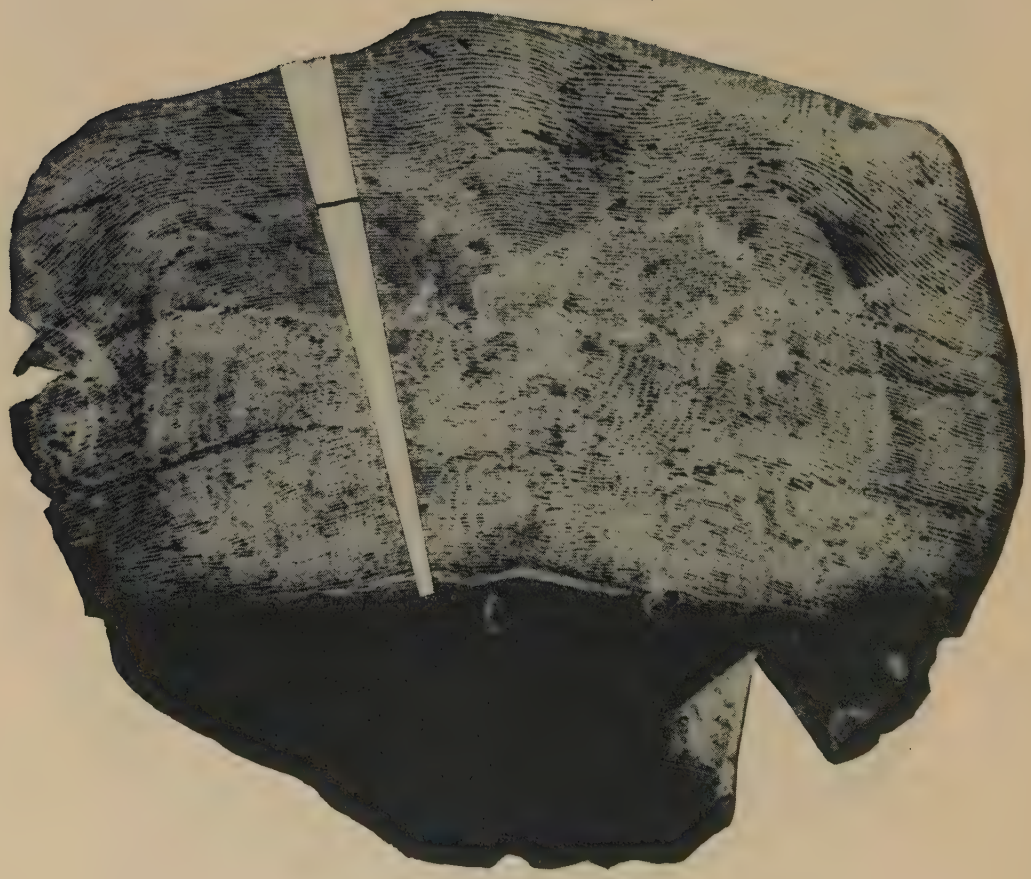

Figure 14. A pilchard scale with one annulus. Body length of fish 137 mm.; caught May 26, 1938.

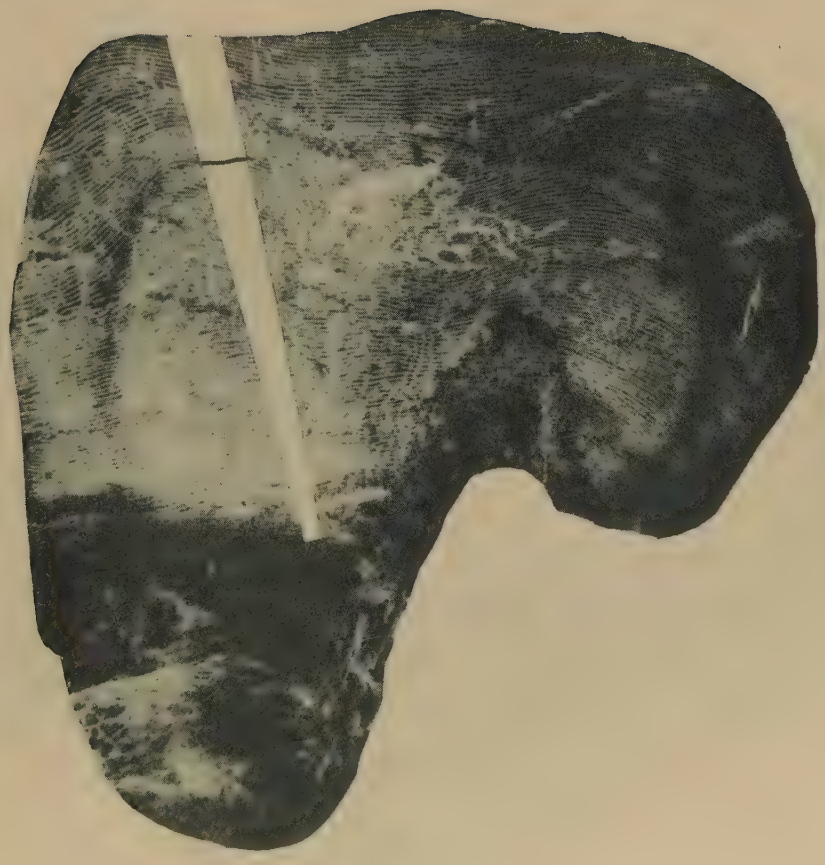

Figure 15. A pilchard scale with one annulus, taken from under the lower margin of the pectoral fin. Body length of fish 123 mm.; caught April 17, 1939.

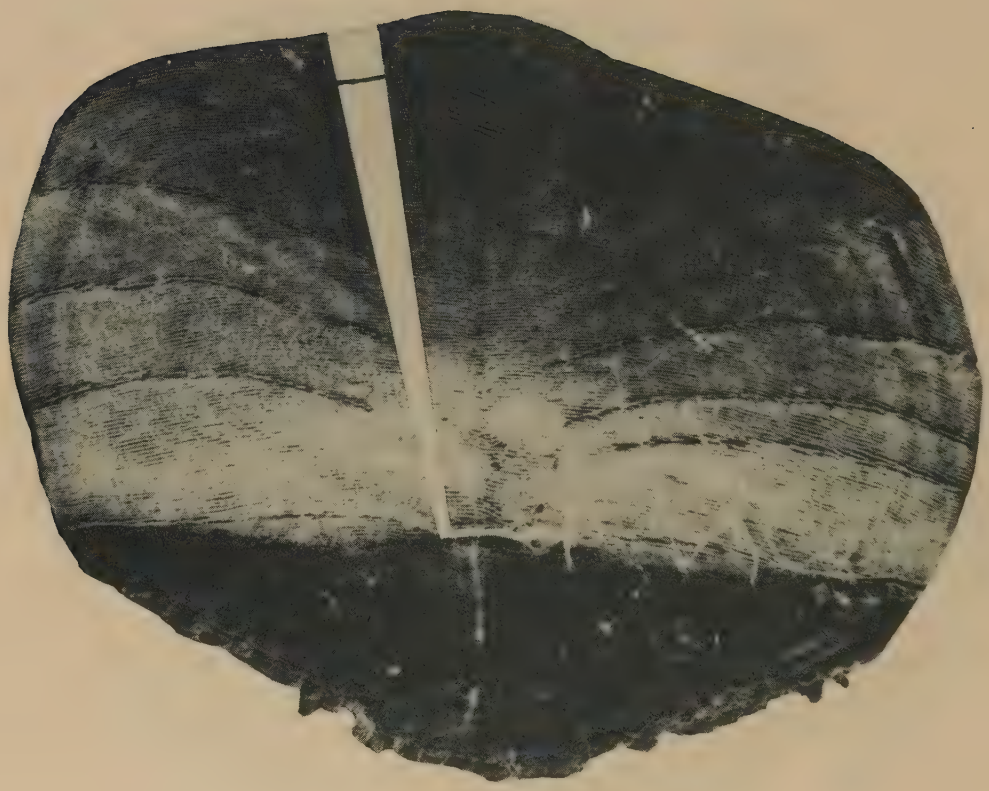

Figure 16. A pilchard scale with one annulus, which is rather obscure. Body length of fish 134 mm.; caught January 26, 1939.

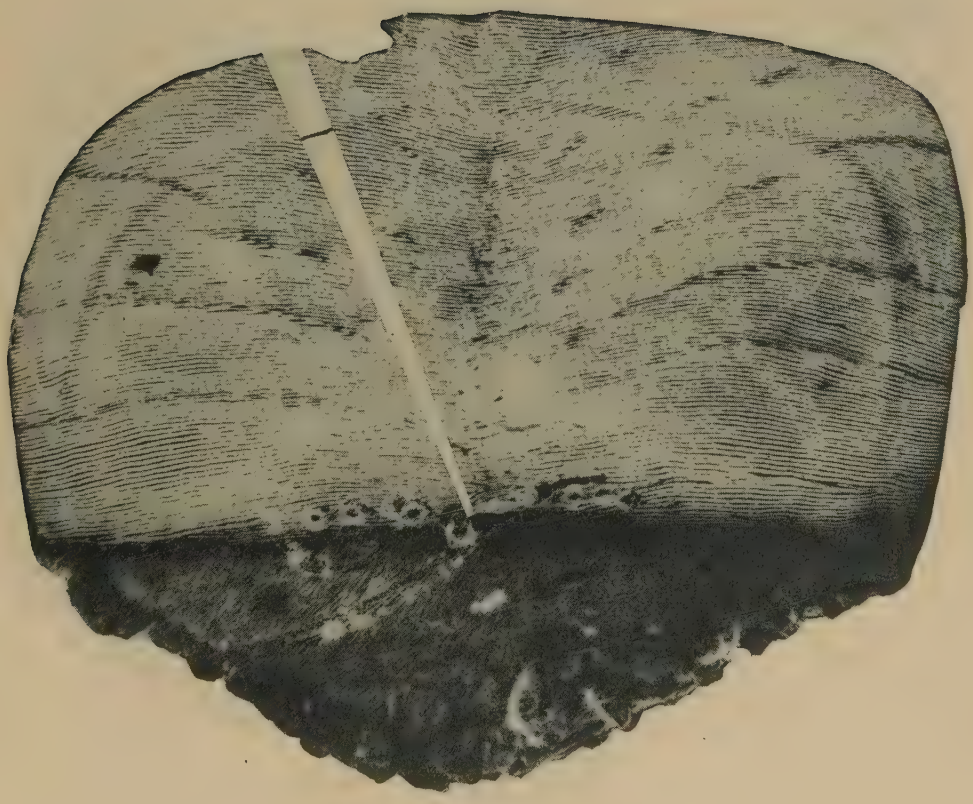

Figure 17. Pilchard scale with one annulus.

Figure 18. Pilchard scale with two annuli. Body length of fish 180 mm.; caught May 9, 1939.

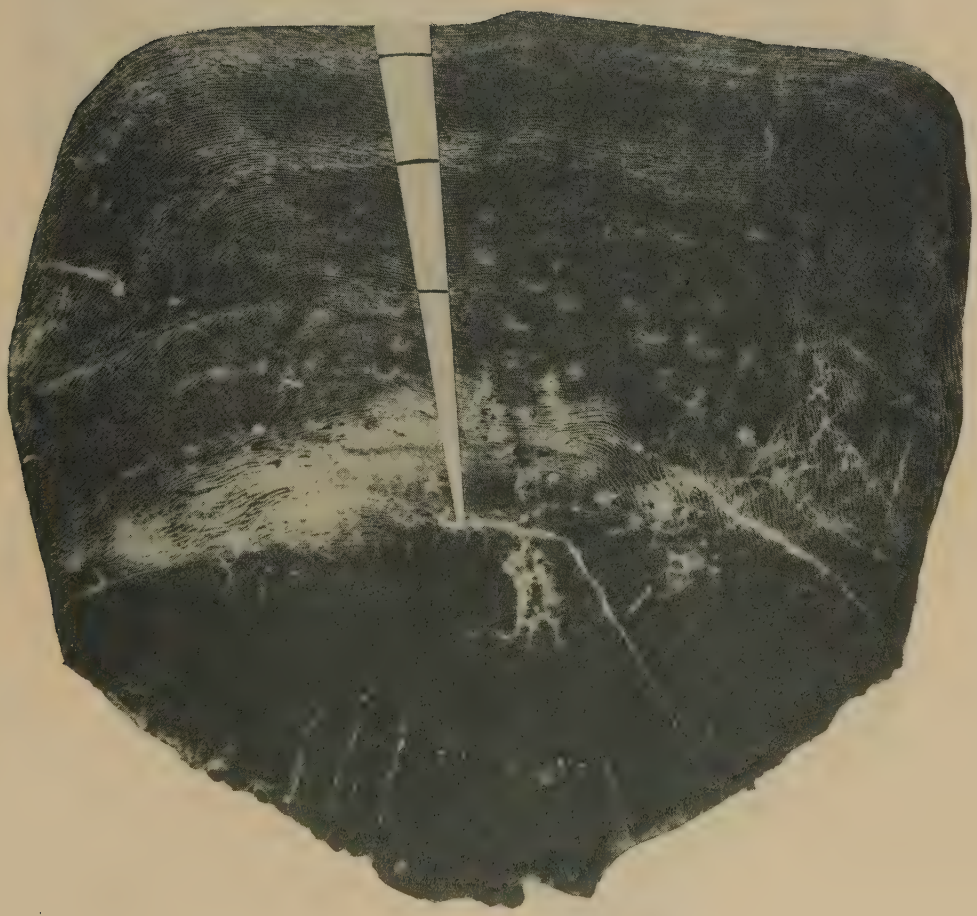

Figure 19. Pilchard scale with three annuli. Body length of fish 199 mm.

Figure 20. Another scale from the same fish as indicated in figure 19, taken from under the lower margin of the pectoral fin.

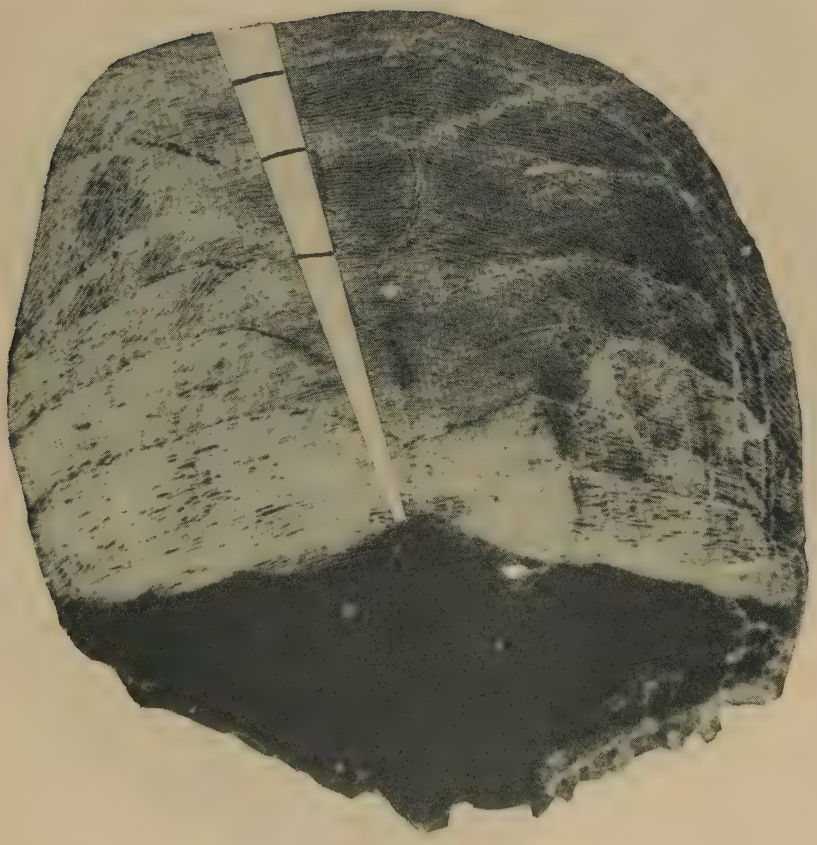

Figure 21. Another scale from the same fish as indicated in figure 19, taken from the caudal peduncle.

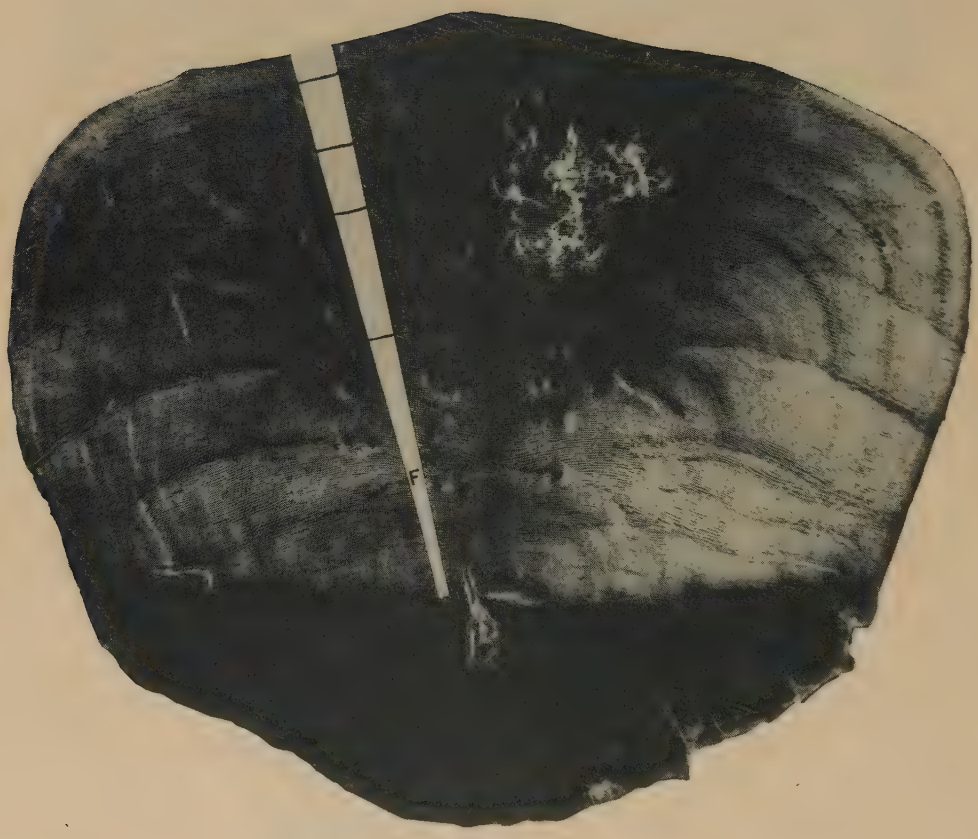

Figure 22. Pilchard scale with four annuli, and with one scar near the center (F). Body length of fish 207 mm.; caught August 3, 1939.

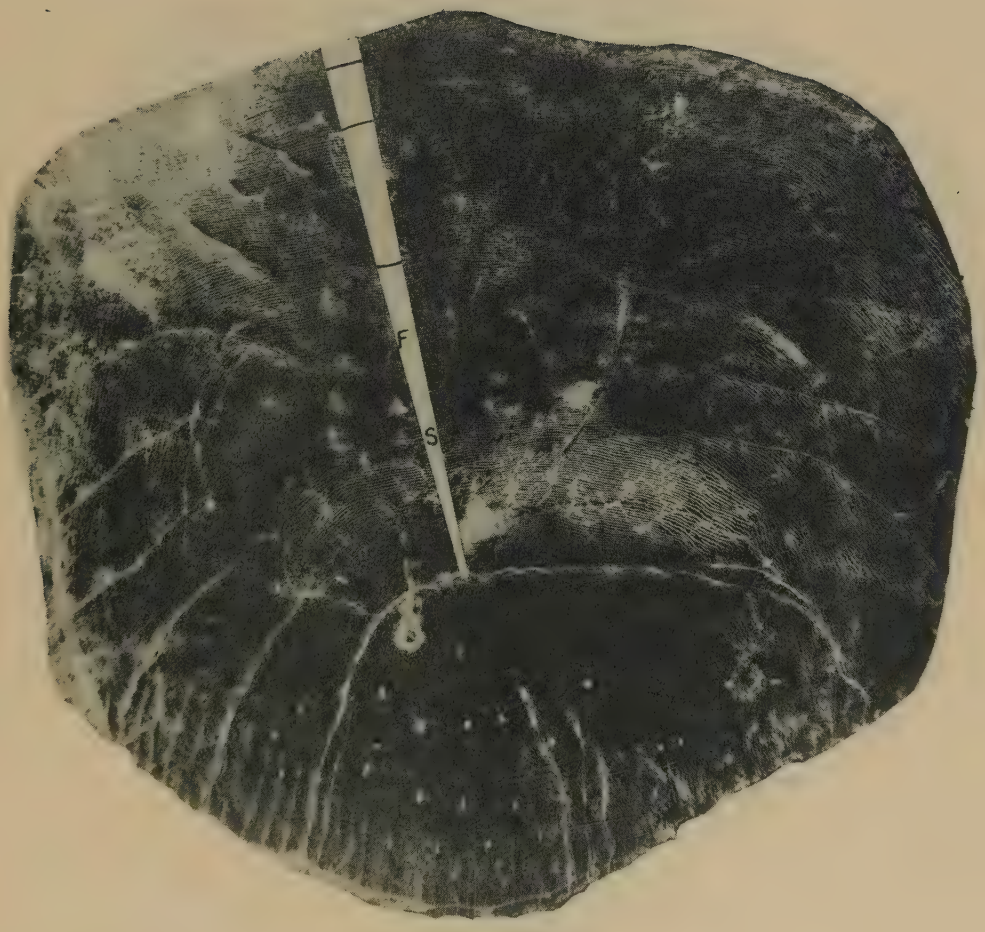

Figure 23. Example of a poorly marked pilchard scale, having three annuli, a false ring (F), and a scar (S) near the center, which might be confused with an annulus (but see figure 24). Body length of fish 215 mm.; caught September 21, 1939.

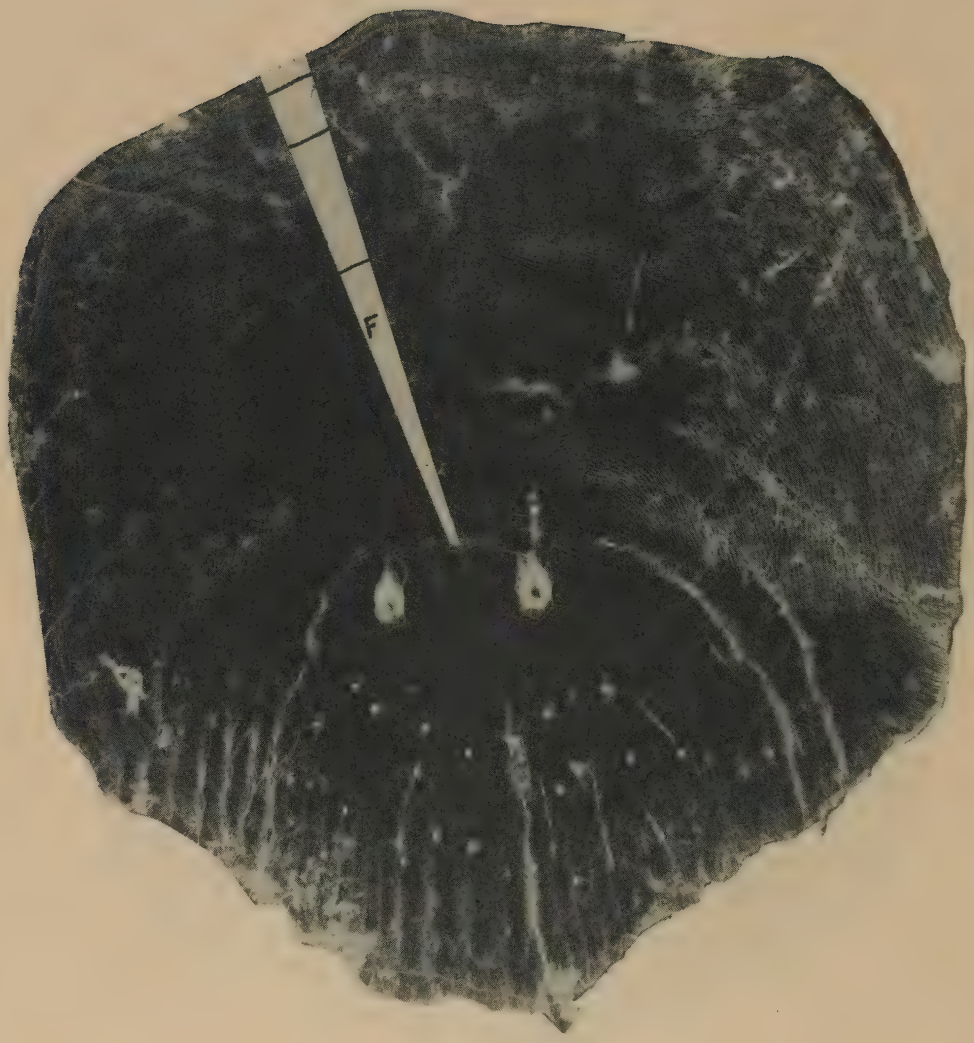

Figure 24. Another scale from the same fish as indicated in figure ~~24~~ 23. Note the false ring (F), and scar-like appearance of the center, where a mark somewhat resembling an annulus appears.

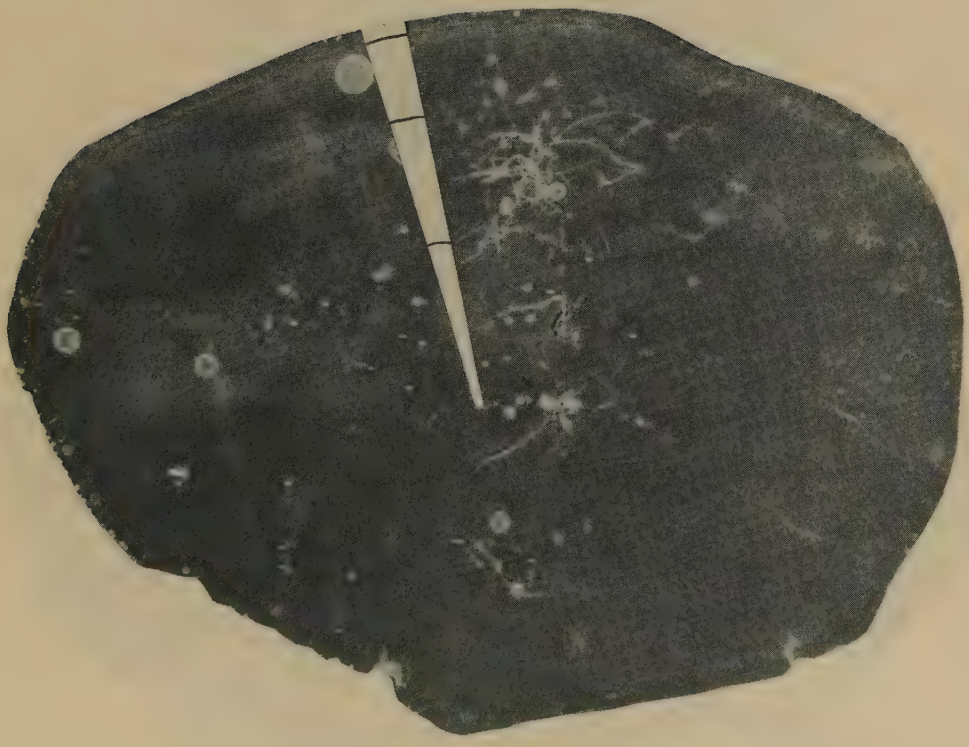

Figure 25. Pilchard scale having three annuli, mounted in glycerine. When mounted in any liquid medium, particularly those with high refractive index, pilchard scales become transparent and the surface structure loses clarity of detail. This effect increases with time, and after a few weeks, a scale so mounted becomes so transparent as to be almost completely invisible, and can then be detected only by close scrutiny at a sharp angle. Body length of fish, 215 mm.; caught August 3, 1939.

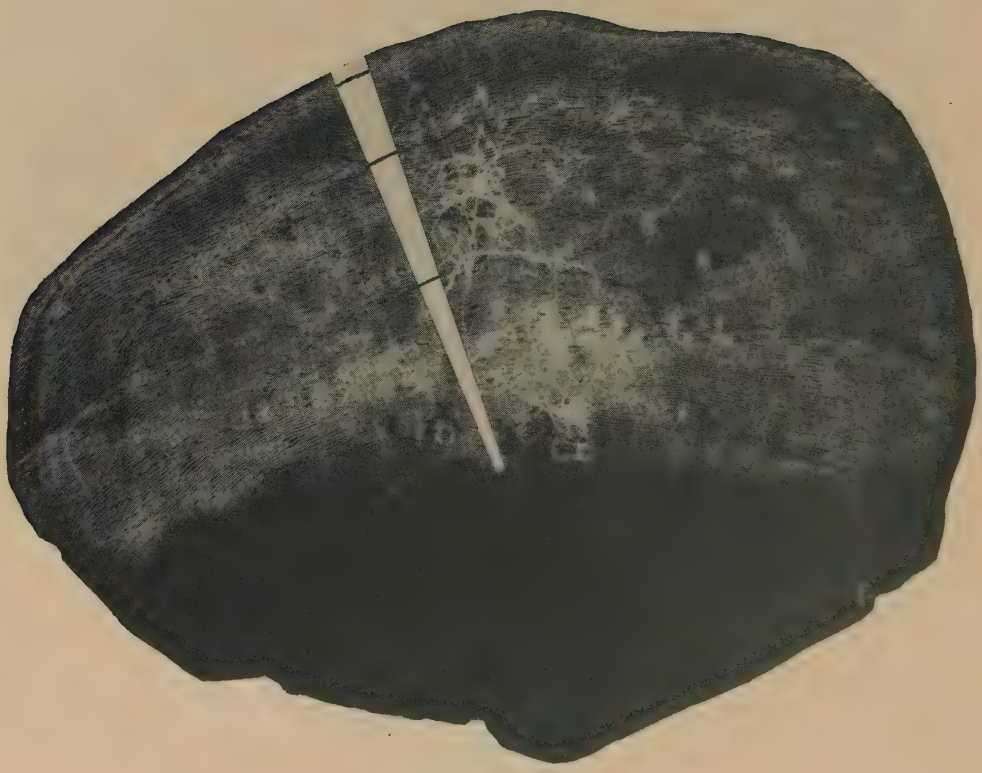

Figure 26. The same scale as shown in figure 25, here mounted dry.

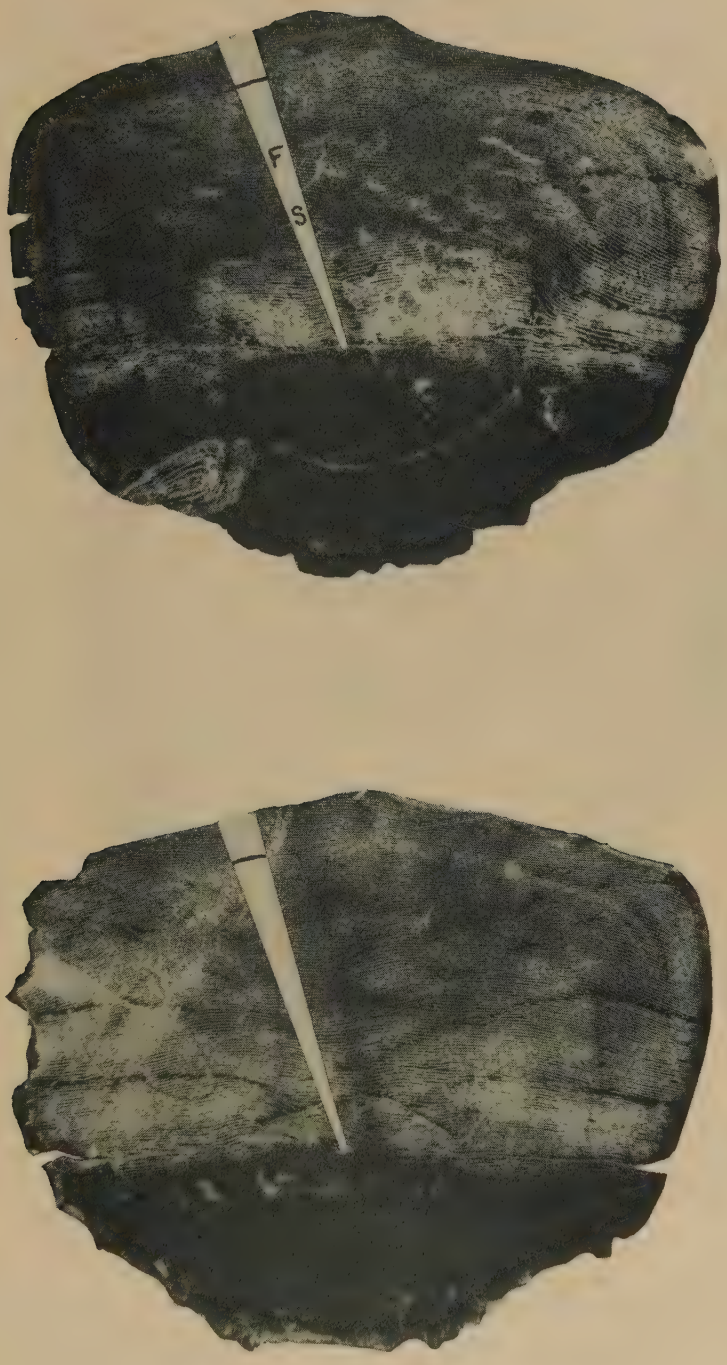

Figure 27. Two scales from a fish 111 mm. in body length, caught March 15, 1939. In the top specimen are seen clearly one annulus and two false rings, (F and S) one of which is easily confused with an annulus. In the lower specimen, only traces of the latter two marks persist, while the true annulus remains evident.

Figure 28. A pilchard otolith with no annulus. Body length of fish 70 mm.; caught June 20, 1939.

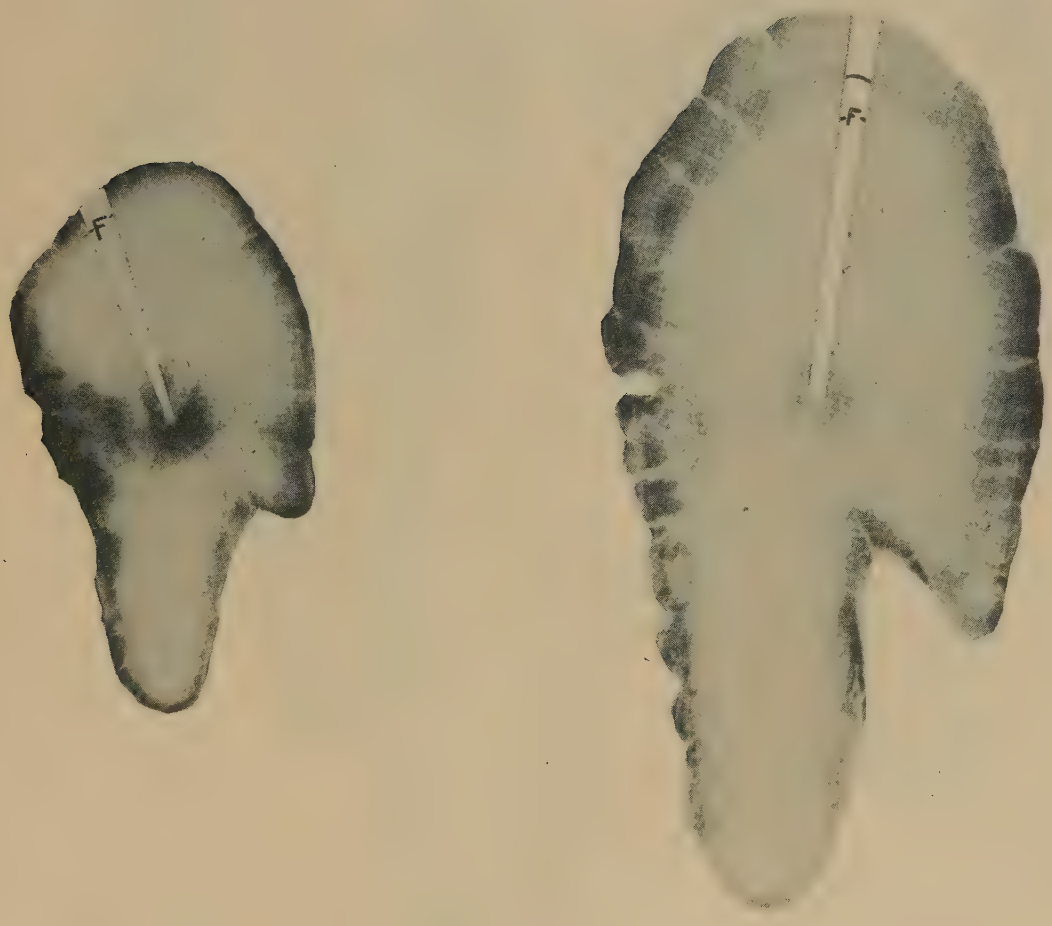

Figure 29. Left, a pilchard otolith with no annulus and a false mark (F) in the growth zone of the first year. Body length of fish 76 mm.; caught June 30, 1938. Right, a pilchard otolith with one annulus some distance from the margin, and with a false mark (F) in the growth zone of the first year. Body length of fish 121 mm. Caught May 24, 1938.

Figure 30. Left, a pilchard otolith with two annuli and a false mark (F) in the growth zone of the first year. Body length of fish 165 mm.; caught January 18, 1939. Right, a pilchard otolith with two well-defined annuli. Body length of fish 151 mm.; caught February 7, 1939.

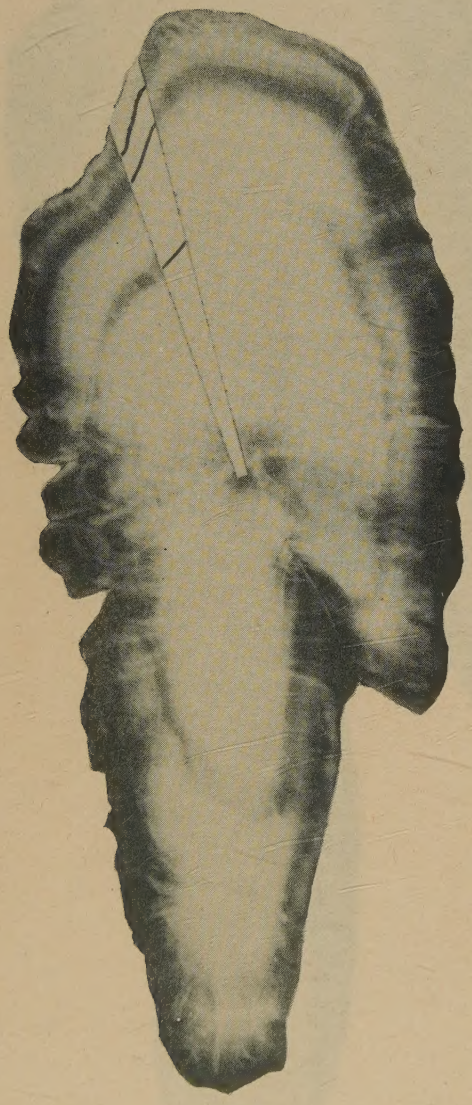

Figure 31. Pilchard otolith with three annuli. Body length of fish 178 mm.; caught January 18, 1939.

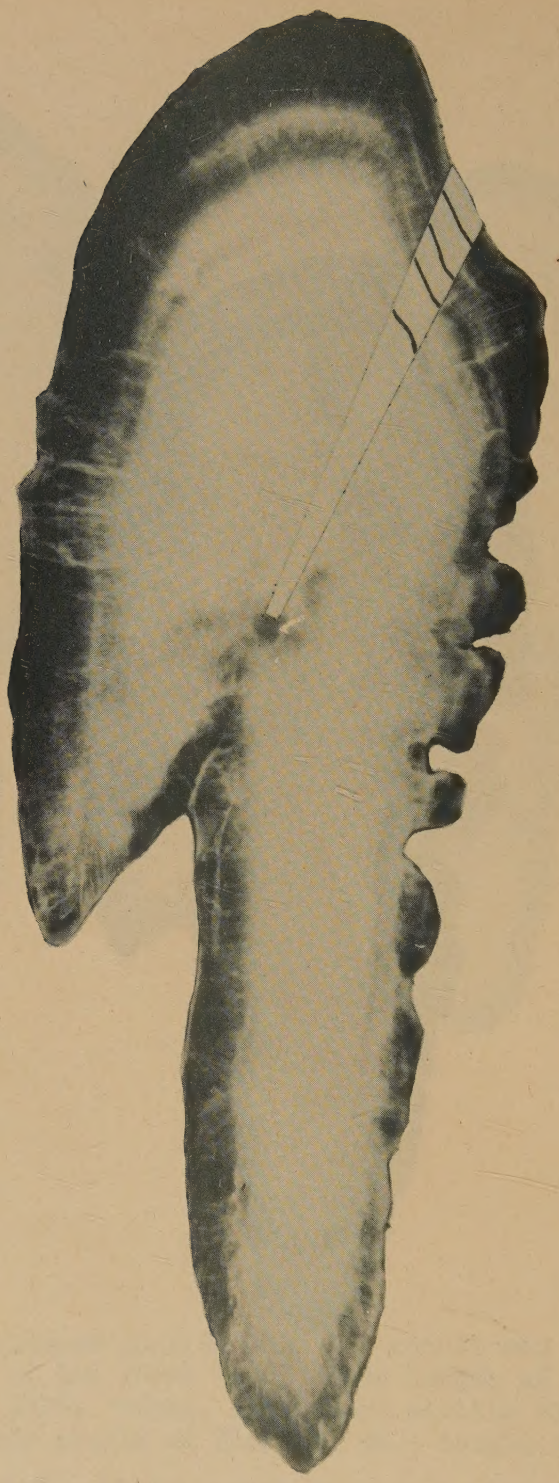

Figure 32. Pilchard otolith with four annuli. Body length of fish 213 mm.; caught August 10, 1939.